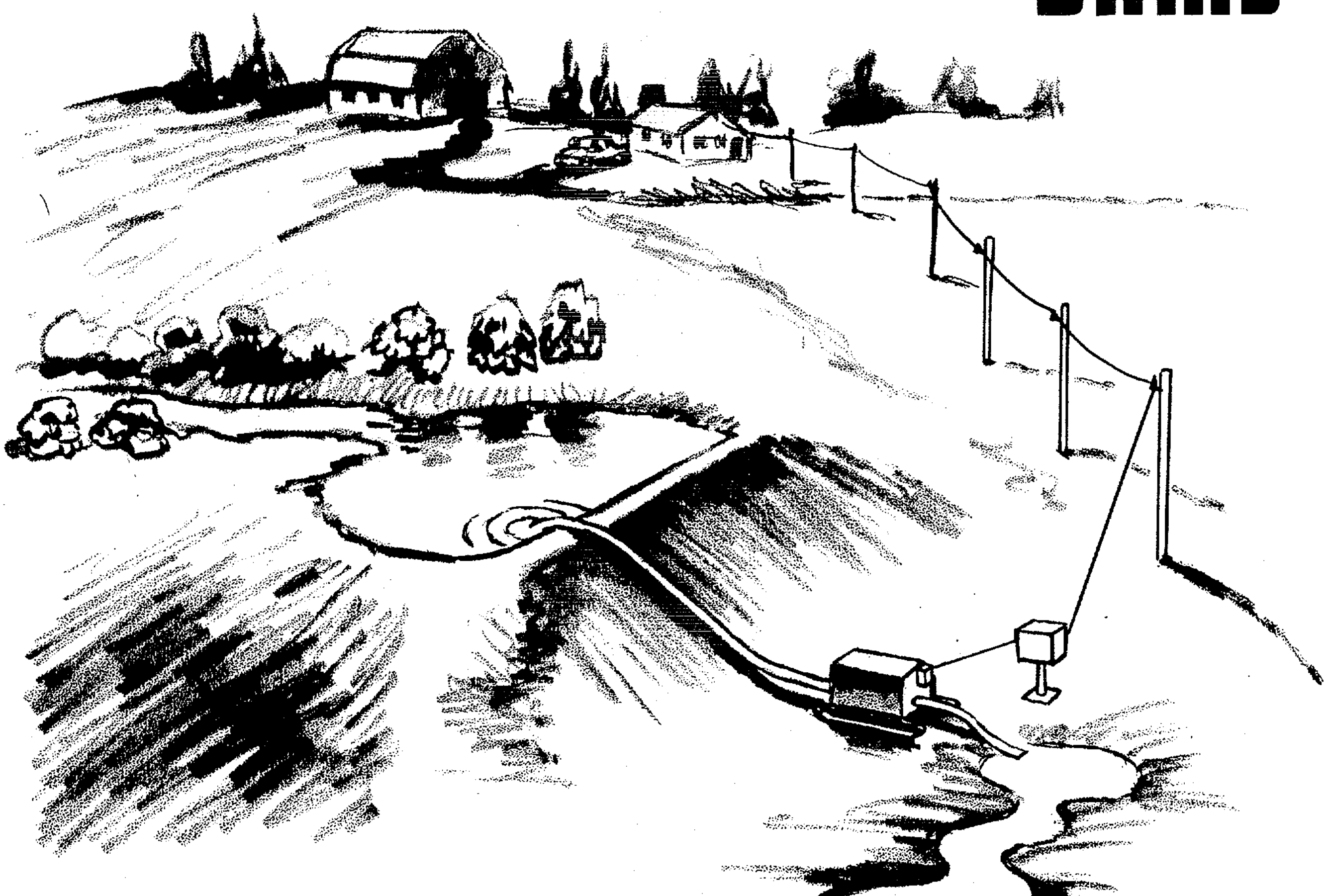
INSTITUTE FOR IWR WATER RESOURCES

U. S. ARMY CORPS OF ENGINEERS

ESTIMATE OF NATIONAL HYDROELECTRIC POWER POTENTIAL AT EXISTING DAMS



JULY 1977

TC 145 .M23

ESTIMATE OF NATIONAL HYDROELECTRIC POWER POTENTIAL AT EXISTING DAMS

A Report Submitted to the
President of the United States of America

by the

U. S. Army Corps of Engineers
Institute for Water Resources

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July 20, 1977 Rev. 2

SYNOPSIS

On April 20, the President submitted a comprehensive energy plan to the Congress. Included in this plan was the following paragraph:

> New or additional hydroelectric generating capacity at existing dams could be installed at less than the cost of equivalent new coal or nuclear capacity. Many of these sites are small, but could generate 3 to 5 megawatts, and are located near major demand centers currently dependent on imported fuel oil. Installation of additional generating capacity at existing sites could conceivably add as much as 14,000 megawatts to the nation's generating potential.

The fact sheet which accompanied this plan stated:

> The President has directed the Corps of Engineers to report within three months on the potential for additional hydropower installations at existing dams throughout the country -- especially at small sites.

The Corps of Engineers Institute for Water Resources designed a 90-day study to determine not only the physical potential of existing dams but also the constraints to the development of this potential. The results of this study are as follows:

1. By installing more efficient turbines and more powerful generators at existing hydropower dams, 5,100 megawatts of capacity could be obtained.

2. By installing additional turbines and generators to existing hydropower dams, 15,900 megawatts of capacity could be obtained.

3. A maximum of 33,600 megawatts could be obtained by constructing powerhouses at all existing non-hydropower dams in the U.S.

4. There are engineering, economic, financial, environmental, social, and institutional constraints to constructing powerhouses at existing non-hydropower dams. Much of the information needed to determine the precise nature and severity of these constraints is not available, but none are considered to be insurmountable.

5. Additional research, with emphasis on the construction of demonstration small-scale hydropower facilities at a number of existing non-hydropower dams, is recommended as a means to better define the constraints which might hinder and the incentives which might accelerate the development of hydropower at such sites.

Although the total potential for hydropower development is small compared to projected U.S. electric generation needs, hydropower, in conjunction with other evolving energy production systems such as solar, wind, tidal, biomass conversion, geothermal and other small-scale techniques, could provide a significant amount of relief to our current dependence on foreign fossil fuels. The development of all of the hydropower potential at existing hydropower and non-hydropower dams could generate almost 160 billion KWH of electricity and save 727,000 barrels of oil per day. This is seven and one-half times the savings associated with the President's goal of solar heating 2-1/2 million homes by 1985.

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PREFACE

This report was prepared by the Corps of Engineers in response to a Presidential request to determine the potential for additional hydropower installations at existing dams throughout the United States--especially at small sites. The results are based on published reports and special studies supplied by the Federal Power Commission and on an intensive 90-day study by the Corps' Institute for Water Resources and the 47 Corps Division and District offices throughout the country.

The objectives of this study are threefold:

1. Estimate the maximum potential conventional hydropower capacity and electricity output which could be developed at existing dams in the United States.

2. Identify the constraints which might hinder or prevent the development of this potential.

3. Identify the means which could be employed to resolve or relax these constraints and the incentives which might be used to spur the development of this potential.

The report is organized into three chapters corresponding to the three objectives plus three appendices. Appendix A contains a detailed description of the method used by the Corps to estimate hydropower potential at existing small dams. Appendix B contains supplemental information on the hydropower potential for each of the 21 major drainage basins in the U.S., Alaska, Hawaii, Puerto Rico, and the Virgin Islands, including a summary of the engineering characteristics of the existing dams in each region. Appendix C contains regional statistics on current competing uses of existing reservoir storage space.

CHAPTER 1

RESOURCE ASSESSMENT

Summary

At the present time, the total maximum potential conventional hydroelectric capacity at existing dams, both developed and undeveloped, is 119.8 million kilowatts capable of generating an average of about 447.1 billion kilowatt-hours annually. Approximately 57.0 million KW, or 47.6 percent of existing dam potential has already been developed. Another 8.2 million KW of capacity is currently under construction. The remainder (54.6 million KW) is the maximum potential capacity which could be achieved by upgrading and expanding existing hydropower dams and by adding hydropower facilities to all existing large and small dams in the United States.

Table 1

Conventional Hydroelectric Capacity
(Constructed and Potential) at Existing Dams

	Capacity (Millions of KW)	Generation (Billions of KWH)
Developed	57.0	271.0
Under construction	8.2	16.8
Total Installed	65.2	287.8
Potential rehabilitation of existing hydro dams	5.1	24.4
Potential expansion of existing hydro dams	15.9	29.8
Potential at existing non-hydro dams greater than 5,000 KW	7.0	20.4
Potential at existing non-hydro dams less than 5,000 KW	26.6	84.7
Total Potential	54.6	159.3
TOTAL (Developed and Undeveloped)	119.8	447.1

Overview of Present U.S. Hydropower Development

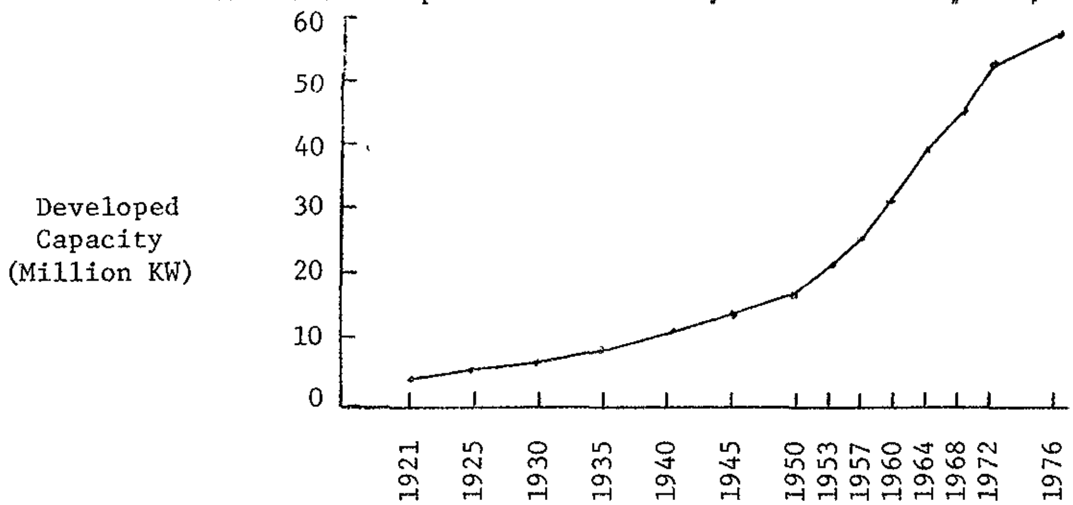
As of January 1, 1976, there were approximately 1,400 conventional hydroelectric power plants in the United States with a total installed generating capacity of 57 million kilowatts (KW). In addition, there were 11 new facilities and 17 expansions under construction with a design generation capacity of 8.2 million KW.[1] Including the expected output of facilities currently under construction, the annual average electricity production from conventional hydropower plants is 287.8 billion kilowatt hours (KWH), compared to a total U.S. electricity production of about 2,000 billion KWH in 1976.

The installed conventional hydroelectric capacity in the country tripled between 1921 and 1940, nearly tripled again between 1940 and 1960, and will double again between 1960 and 1980. However, much of the recent growth in capacity results from the construction and operation of pumped storage plants. Pumped storage plants are a special type of hydroelectric facility which are not included in the statistics reported in this study, since the physical potential for pumped storage is virtually unlimited.

The continuing growth in hydroelectric capacity has been overshadowed by a faster rate of expansion of steam-electric generating capacity. In the 1920's conventional hydroelectric plants provided as much as a third of the total generating capacity of the United States. They now contribute only about 13 percent of the U.S. electricity requirements.

Figure 1

Trend in Developed Conventional Hydroelectric Capacity



[1]Federal Power Commission, "Hydroelectric Power Resources of the United States," U.S. Printing Office, Washington, D.C., January 1, 1976

Total Hydropower Potential at Existing Dams

The maximum potential for conventional hydroelectric development at existing dams in the United States is 54.6 million kilowatts (KW), with an expected production of 159.3 billion kilowatts-hours (KWH) of electric energy per year. The complete development of this amount of capacity and generation could defer 15.3 percent and 8.65 percent of the projected growth in steam-electric capacity and generation during the period 1975-1985.[2] Using the commonly accepted ratio of 1 barrel of oil = 600 KWH at the point of consumption, the complete development of all hydropower potential at all existing U.S. dam sites represents a savings in oil consumption equivalent to 727,000 barrels per day.

This estimate of conventional undeveloped water power is an upper bound on the physical potential for hydroelectric development at 49,500 existing dams in the United States. The estimate does not include detailed consideration of engineering, economic, financial, or environmental feasibility; it does not consider the competitive use of water impounded by these dams; and it does not include consideration of the many institutional and legal problems which must be overcome to fully develop this energy resource. Considerations of these factors will undoubtedly place limits on the amount of this potential which can be justified. On the other hand, this estimate does not include an important factor which could increase this potential, namely, operating series of dams as systems to increase the potential of each individual dam.

The derivation of the national estimate relies on two sources: (1) the Federal Power Commission publication entitled "Hydroelectric Power Resources of the United States - Developed and Undeveloped," dated January 1, 1976; and (2) a special study performed by the Corps of Engineers between April and July 1977. The FPC inventory contains estimates of hydropower potential at dams or sites with a capacity of 5,000 KW or greater. The Corps study was thus directed toward existing dams with capacity potential less than 5,000 KW.

Potential at Existing Dams over 5,000 KW

The FPC systematically compiles statistics on hydropower potential for dams on sites over 5,000 KW capacity using data from Federal and State river basin studies and project feasibility reports, from studies performed by industry and private utilities, and from applications for FPC licenses. Where such studies are not available, and potential is known to exist at a site, the FPC estimates average streamflow at the site, the actual or expected amount of hydraulic head, assumes an efficiency based on the type of turbine which is likely to be installed, and computes hydropower potential. The determination of nameplate capacity and of actual electricity produced

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[2]U.S. Water Resources Council, "Water for Energy," draft report, February 1977, pp A-6 to A-27

in KWH is based on an assumed operation mode for the power plant, which in turn is based on the ability of the dam to supply either base load or peak load power.

The FPC estimates are site-specific, are usually based on a preliminary assessment of engineering, economic, and financial feasibility, and frequently include some consideration for current and projected needs for flood control, water supply, navigation, and other non-hydropower reservoir storage uses.

The Corps performed a special study to determine the proportion of hydropower potential for dams listed in the FPC inventory which can be attributed to existing dams as opposed to undeveloped dam sites. The potential at listed hydropower dams which could be expanded to include additional turbines and generators is 15.9 million KW and 29.8 billion KWH. The potential at listed non-hydropower dams which could be retrofitted with a powerhouse is 7.0 million KW and 20.4 billion KWH. No data for the expansion potential of existing hydropower dams below 5,000 KW rated capacity were available.

In addition to expansion potential, many existing hydropower plants could be renovated with more efficient turbines and more powerful generators. This potential for hydropower development has also been included in the national estimate. A recent GAO report[3] concludes that the capacity and electricity generation of existing Federal hydropower dams could be increased between 1 and 10 percent by installing new turbines and generators and by replacing old and worn components. Efficiency increases which averaged 9 percent were cited for 7 recent U.S. and Canadian public power plant rehabilitation projects. It is assumed that both public and private power dams in the U.S., particularly older dams, could be similarly fitted with new turbines and generators. Applying an average increase in efficiency of 9 percent to approximately 1,400 existing hydropower facilities produces an additional hydropower potential of 5.1 million KW and 24.4 billion KWH of generation.

To summarize, if all existing hydropower plants over 5,000 KW capacity were rehabilitated, if existing hydropower dams with expansion potential were enlarged, and if all identified existing non-hydropower dams with hydropower potential over 5,000 KW were fitted with conventional turbines, national electricity capacity and generation could be increased by 28.0 million KW and 74.6 billion KWH, respectively.

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[3]U.S. General Accounting Office, "Power Production at Federal Dams Could be Increased by Modernizing Turbines and Generators," Case No. OSD 4587 March 16, 1977.

Table 2

Potential at Existing Dams Greater than 5,000 KW Capacity

	Capacity (Million KW)	Output (Billion KWH)
Increase due to rehabilitation of existing hydropower dams	5.1	24.4
Expansion of existing hydropower dams	15.9	29.8
Installation of hydropower at existing non-hydropower dams	7.0	20.4
TOTAL	28.0	74.6

Potential at Existing Dams Less than 5,000 KW

The remainder of the national estimate for hydropower potential at existing dams is due to the developable capacity at existing small dams, defined as dams less than 100 feet in height, less than 10,000 acre-feet of reservoir storage capacity, and with a potential capacity less than 5,000 KW.

The Corps estimate of national hydropower potential at existing small dams is 26.6 million KW, with a potential energy yield of 84.7 billion KWH. Due to the short time duration of the study, it was not possible to compute the power potential at each of the individual small dams in the U.S. Instead, the following method was used:

1. Existing small dams in each river basin were grouped into categories with similar hydraulic head and reservoir storage characteristics.

2. Each river basin was partitioned into streamflow zones.

3. Typical dams from each of the small dam categories were allocated to appropriate streamflow zones.

4. The maximum power potential for each typical dam was determined by using average streamflow, maximum hydraulic head, maximum use of reservoir storage for power production, and maximum efficiency parameters in the hydropower formula $(P = \frac{Qhe}{11.8})$.

5. The energy potential of a dam was determined by adjusting power potential to account for the dependability and variation of streamflow in each streamflow zone.

6. Design capacity was determined by assuming the most likely operating mode for each typical dam based on the relationship between usable streamflow and reservoir storage.

7. Energy and capacity figures for each typical dam were multiplied by the number of dams in each category to compute the total electrical generation and capacity potential of all existing small dams in a basin.[4]

This method was applied by planners and engineers in each District office to river basins within their jurisdiction. Knowledge of unique local factors which might affect streamflow or the distribution of existing dams was fully utilized in determining streamflow zones and allocating representative dams to the various zones. This analytical approach, which merges a technically sound estimation procedure with field-based expertise and experience, provides a reasonable estimate of maximum physical hydropower potential.

Regional Analysis

Figure 2 and Tables 3 and 4 contain statistics on the distribution of hydropower potential at existing dams for each of the 21 major drainage areas of the United States.

The hydropower potential at existing dams varies widely throughout the nation. The physical factors which create regional hydropower potential (amount of precipitation runoff, number of existing dams, and topographic relief) vary considerably between the Northwest, the Eastern Seaboard, the Great Plains, and the Southwest. The Pacific Northwest has both the largest installed capacity and the largest hydropower potential of any major river drainage area in the U.S. This region alone has almost as much capacity potential as all the regions west of the Appalachians and east of the Sierra Mountains combined, and would probably have more potential than the U.S. Midlands if the region had the same proportion of small dams per square mile of drainage area commonly found in more densely settled and more extensively developed areas in the East and Midwest.

For the remainder of the regions, hydropower potential is fairly proportional to the size of the region, with large regions (Mid-Atlantic, South Atlantic-Gulf, Ohio River, etc.) exhibiting large potential and small drainage basins (such as Hudson Bay and Hawaii) with small potential. Notable exceptions are the large regions in the Southwest (Texas-Gulf, Rio Grande, Colorado, and the Great Basin) where arid conditions and low streamflows are prevalent.

Table 5 shows the expected growth in regional steam-electric capacity and generation between 1975 and 1985 for each major river drainage and the percentage which could be deferred by the full development of hydroelectric power at existing dams. Nationally, the maximum development of hydropower at existing dams could defer 15.4 percent of expected capacity growth and 8.6 percent of generation growth, with the most significant effects occurring in the Columbia-Northwest Pacific, New England, Mid-Atlantic, Upper Mississippi, Lower Mississippi, and Alaska regions. The New England potential is particularly important because of the region's relatively high electricity costs and its dependence on foreign crude oil.

[4]An expanded explanation of the methodology is contained in Appendix A of this report.

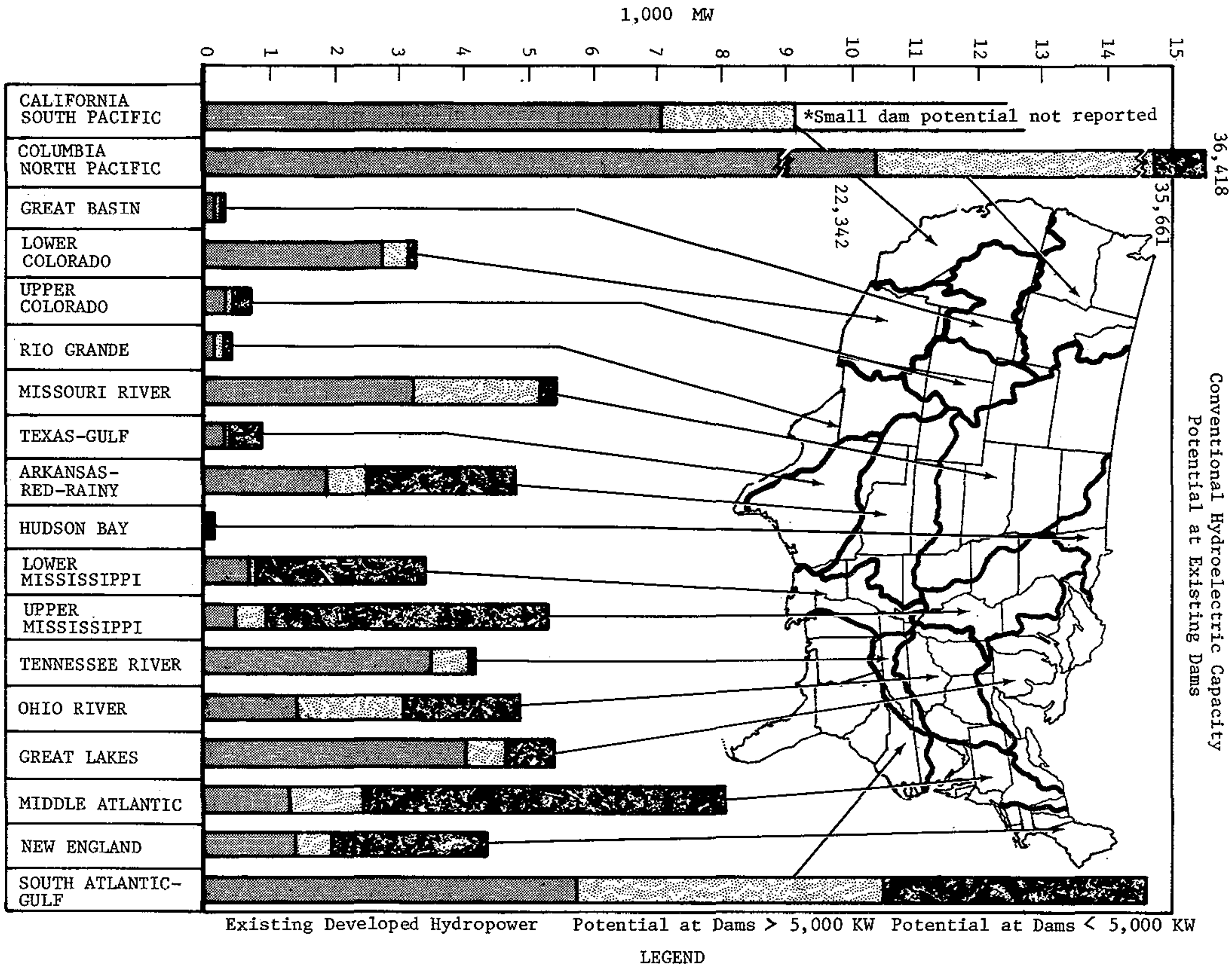

Figure 2
Conventional Hydroelectric Capacity
Potential at Existing Dams

Table 3

Conventional Hydroelectric Capacity Potential at Existing Dams

	Existing Capacity (MW)	Rehabilitation Potential (MW)(9%)	Hydro Expansion Potential (MW)	Hydro Installation Potential (MW)	Small Dam Potential (MW)	Total Regional Potential (MW)
New England	1,427	127	188	223	2,432	2,970
Mid-Atlantic	1,290	116	565	521	5,580	6,782
South Atlantic-Gulf	5,753	518	3,342	874	4,244	8,978
Great Lakes	4,008	360	253	143	644	1,400
Ohio River	1,465	132	19	1,414	1,873	3,438
Tennessee River	3,658	329	30	0	75	434
Upper Mississippi River	581	52	80	199	4,378	4,709
Lower Mississippi River	724	18	88	25	2,582	2,713
Hudson Bay	13	1	0	0	51	52
Arkansas-White-Red River	1,839	165	236	245	2,318	2,964
Texas-Gulf	393	35	11	43	460	549
Missouri River	3,370	303	1,037	486	250	2,076
Rio Grande River	65	6	20	130	184	340
Upper Colorado River	359	32	15	24	465	536
Lower Colorado River	2,847	256	0	59	87	402
Great Basin	530	48	1	0	85	134
Columbia-North Pacific	22,342	2,010	10,681	628	757	14,076
California-South Pacific	7,050	634	970	514	*	2,118
Alaska	123	11	36	46	25	118
Hawaii	18	2	1	0	30	33
Puerto Rico	0	0	0	0	10	10
Virgin Islands	0	0	0	0	0	0
TOTALS	57,855	5,155	17,573	5,574	26,530	54,832

* No estimate was available for the California-South Pacific Region

Table 4

Conventional Hydroelectric Energy Yield Potential at Existing Dams

	Existing Energy Yield (10^6 KWH)	Rehabilitation Potential (9%)	Hydro Expansion Potential	Hydro Installation Potential	Small Dam Potential	Total Regional Potential (10^6 KWH)
New England	5,719	515	502	517	11,685	13,219
Mid-Atlantic	5,201	477	1,945	792	15,279	18,493
South Atlantic-Gulf	14,521	1,307	9,228	1,255	21,846	33,636
Great Lakes	24,754	2,228	578	580	2,423	5,809
Ohio River	5,505	495	100	4,680	2,849	8,124
Tennessee River	16,112	1,450	139	0	371	1,960
Upper Mississippi River	3,006	270	260	1,077	8,991	10,598
Lower Mississippi River	424	38	136	104	8,110	8,388
Hudson Bay	68	6	0	0	72	78
Arkansas-White-Red River	5,019	452	269	322	6,525	7,568
Texas-Gulf	1,074	97	6	61	1,095	1,259
Missouri River	15,294	1,376	4,632	1,106	580	7,694
Rio Grande	234	21	49	311	788	1,169
Upper Colorado River	1,634	147	80	49	593	869
Lower Colorado River	10,541	579	0	289	526	1,394
Great Basin	1,976	178	1	0	179	358
Columbia-North Pacific	127,182	11,446	14,865	2,949	2,495	31,755
California-South Pacific	33,400	3,006	3,264	2,304	*	8,574
Alaska	493	44	141	239	112	536
Hawaii	104	9	8	0	40	57
Puerto Rico	0	0	0	0	129	129
Virgin Islands	0	0	0	0	0	0
TOTALS	272,261	24,141	36,203	16,635	84,688	161,667

* No estimate was available for the California-South Pacific Region

Table 5

Maximum Potential Deferment of Expected Steam-Electric Growth between 1975-1985 by Full Development of Hydropower at Existing Dams

River Region	Projected Steam-Electric Growth (1975-1985)		Percentage of Possible Deferment by Hydropower Development at Existing Dams	
	Capacity (million KW)	Generation (billion KW)	Capacity	Generation
New England	8.49	53.2	35.0%	24.8%
Mid Atlantic	28.32	170.7	24.0%	10.8%
South Atlantic - Gulf	85.82	396.5	-10.5%	-8.5%
Great Lakes	23.12	155.7	6.1%	3.7%
Ohio River	39.88	183.65	-8.6%	-4.4%
Tennessee River	16.96	65.74	2.6%	3.0%
Upper Mississippi River	24.14	132.97	19.6%	8.0%
Lower Mississippi River	13.01	67.10	20.7%	12.5%
Hudson Bay	-0.4	-0.5	See Footnote	See Footnote
Arkansas-White-Red River	20.89	111.40	14.2%	6.8%
Texas - Gulf	31.28	146.81	1.7%	0.9%
Missouri River	22.18	118.83	9.3%	6.5%
Rio Grande	0.11	-1.05	See Footnote	See Footnote
Upper Colorado River	8.00	34.15	6.7%	2.5%
Lower Colorado River	5.64	31.74	-7.1%	-4.4%
Great Basin	3.5	20.55	-3.8%	1.7%
Columbia - North Pacific	6.37	41.60	100.0+%	76.0%
California - South Pacific	13.51	87.73	15.6%	9.7%
Alaska	0.25	1.14	47.1%	47.0%
Hawaii	1.03	5.1	3.2%	1.1%
Puerto Rico - Virgin Islands	3.80	17.26	0.3%	0.7%
TOTAL	355.90	1,840.31	15.4%	8.8%

*Imported electricity from outside the region are predominate, thus deferment figures are not applicable here.

CHAPTER 2

CONSTRAINTS TO HYDROPOWER DEVELOPMENT AT EXISTING DAMS

Introduction

Chapter 1 contains summary statistics of maximum physical hydropower potential at existing dams for each region of the U.S. and for the nation. In this chapter the constraints which will inhibit the full development of hydropower at existing dams will be described. The barriers to large-scale hydropower development and to small-scale hydropower development at existing dams are similar, but small-scale development involves unique considerations which have not previously been documented. Therefore, although the following discussion applies to both categories, the emphasis will be on constraints to small-scale development.

The conversion of hydropower potential into electricity on line is subject to a number of engineering, financial, legal, institutional and other considerations. An exhaustive study of each of these considerations is necessary before the overall feasibility of hydropower development at existing dams can be precisely determined. Within the limitations of this 90-day study, it is possible only to (1) assess the type of considerations which might constrain hydropower development; (2) analyze in general their possible nature and significance, and (3) formulate general approaches to further detailed investigations of potential constraints.

1. Engineering Constraints

Engineering factors relevant to this review include: (a) engineering techniques for designing small powerhouses and low head/low-flow turbines; (b) the difficulty and cost of rehabilitating existing dams; and (c) design of electricity delivery systems which integrate small-scale hydropower production into a regional or area supply network.

(a) Hydropower engineering considerations.

A hydraulic turbine operates according to effective hydraulic pressure and quantity of water flow. The absolute lower limit at which a turbine will operate efficiently is not known, but 16,700 of the dams analyzed during this study (34 percent of the existing dams in the U.S.) have hydraulic heads of only 6 to 20 feet.

A comprehensive study of the electro-mechanical technology of small-scale powerhouse and turbine design was not performed for this study. It is reported[5] that European and Asian engineers are routinely designing and

[5] A recent issue of Engineering News Record magazine (June 2, 1977, p 8) reports that there are 40 European manufacturers of small turbines. The article also states that the USSR reportedly builds turbines as small as 5 kilowatts design capacity.

constructing small-scale hydropower turbines and generators. Only one large company and several small firms in the United States have designed, constructed, and installed small-scale hydropower facilities. The reason for the low level of U.S. design and manufacturing activity is the lack of interest in and demand for small-scale hydropower prior to recent fossil fuel price increases. Based on the presumed success of overseas installations, there should be no insurmountable electro-mechanical design problems.

However, an active program in small-scale hydropower development would require simplified planning techniques to determine the capacity and energy yield at potential small-scale hydropower sites. The current practice of custom designing the hydropower facilities at each individual hydropower site would prove too cumbersome and too expensive. Given a demand for small-scale hydropower development, it is likely that planning and design techniques could be readily derived.

(b) Rehabilitation considerations.

Many of the dams included as potential power producers are very old and may be in need of extensive rehabilitation. Many earth and rockfill structures have effective lives of 100 years or more, but concrete dams (gravity, buttress, arch, and multi-arch dams) begin to display serious evidence of stress and decay after 50 years. Of the dams listed in the Corps inventory, 8,100 (16.4 percent) were constructed before 1930 and of these, 2,200 are concrete dams. Assuming prohibitive rehabilitation costs for half of the concrete dams built prior to 1930, the estimate of hydropower capacity and generation would be reduced by 1.8 million KW and 5.7 billion KWH, respectively. The reduction would be greatest in the New England, Mid-Atlantic, and Ohio regions, where old concrete dams comprise 27 percent, 13 percent, and 20 percent of the regions' dams respectively.

Reservoir storage capacity is also a function of the age of a dam. On the high silt load streams in the Midwest and West, all types of dams will have lost much of their effective storage capacity and regulation capability after 50 years. Assuming that half of the 2,185 pre-1930 dams in the seven Midwest and Southwest regions retain only 50 percent of their effective storage capacity, the regional estimate of hydropower capacity and generation for these seven regions would be reduced 1.0 million KW and 2.6 billion KWH, respectively.

The above assumptions regarding the extent of needed rehabilitation and lost storage are necessary because more precise information is not available. A preliminary engineering feasibility study of the nation's inventory of existing dams is required both to more precisely define energy potential and to determine the overall safety and reliability of many potential hydropower installations. Furthermore, it is likely that many hydropower conversions would involve raising the height of dams to capture additional hydropower storage. Adding new stresses to old dams is a significant factor for consideration in any small-scale hydropower development program.

(c) Network technology considerations.

It is difficult for a utility engineer to design power plants and power transmission systems capable of meeting demand for electricity if a substantial part of the capacity is subject to the vagaries of nature. Modern high-speed computers and complex system interties are invaluable in matching demand with supply, but even in a system dominated by large steam-electric plants where fuel inputs can be completely controlled, occasional shortfalls occur and are difficult to adjust for.

Network considerations involve the reliability of power produced by small dams. Approximately 30,100 (60.8 percent) of the 49,500 dams in the U.S. are located on streams which dry up from 1 week to 6 months almost every year. These dams have been included as potential energy producers even though standard analysis procedures which use firm yield (or constantly reliable streamflow) as a basis for estimating potential would result in zero capacity for these dams. Dams of this type, located in intermittent or frequent-zero streamflow zones, have a reported capacity of 1.4 million KW and an expected generation of .83 billion KWH per year. Finally, many of the dams in the inventory are constructed in remote locations which would require the construction of inordinately expensive transmission lines. The data to estimate the reduction in capacity and generation due to this factor are not available.

2. Economic Feasibility Constraints

The economics of small-scale hydropower development is one of the most significant of all of the constraints discussed in this chapter. On the one hand, logic leads to the conclusion that if hydropower at new sites is already competitive with alternative energy sources in many regions of the country, then hydropower at existing dams must be even more competitive because the capital cost of constructing the dams is a sunk cost. On the other hand, if hydropower at existing dams is cost competitive, one might expect at least a modicum of activity by public and private utilities and industry to develop this resource for profit. Yet a recent survey of 30 utilities[6] shows only a few are even remotely interested in hydropower, much less small hydropower development. In fact, prior to the recent oil embargo, small hydropower plants were still being retired at a regular rate.[7]

Table 6

Retired Hydropower Capacity

Time Period	Retired Capacity (KW)
1940-1950	104,360
1951-1960	87,152
1961-1970	238,747
1970-1976	146,944

[6]Engineering News Record, June 2, 1977, p 6.
[7]FPC

A few generalizations are possible with respect to the relative economic and resource efficiency of hydropower. In terms of economic efficiency, hydropower has several general inherent advantages over thermal power. The useful life of structures is two to three times longer than thermal plants and equipment, hydropower consumes no fuel (a major cost item for thermal power generation), operation and maintenance costs are lower because equipment is less complex, and hydropower is capable of almost instantaneous response to increased load demands.

These inherent advantages have historically been offset by the fact that initial investment costs per unit of capacity have been greater for hydropower than for thermal plant and equipment. But this advantage is now being narrowed by the sharp increases in fuel costs and investment costs associated with the siting and construction of fossil fuel and nuclear plants, including cost increases associated with equipment and operating costs for air and water pollution control. For example, a recent MITRE Corporation study of electrical generation costs in New England concludes "...in 1955, to develop a potential hydro site at a .7 plant factor, a private utility could afford to spend a maximum of about $825/KW in 1975 dollars ($291/KW in 1955 dollars); by 1981 the utility can spend up to $1,490/KW in 1975 dollars ($1,997/KW in 1981 dollars). In short, many sites which were formerly uneconomic may now be competitive."[8]

The traditional advantage of steam-electric power is narrowed, and perhaps reversed, for hydropower development at existing dams, since the capital costs of constructing the dam have already been made. However, in the case of hydropower development at existing dams, the assumption of zero cost for the "fuel" (water) which powers the turbine is no longer applicable. Almost all existing reservoir storage is currently being used for some productive or socially important purpose. Reservoir space is used to store municipal, industrial, and agricultural water supplies, for navigation, flood control, water quality control, and recreation, as well as for hydropower production. Some uses are not competitive, as in the case of reservoir releases for downstream water quality control which can be passed through a turbine without loss of function. However, reservoir space reserved for flood waters cannot be simultaneously used to store hydropower water. Water supply storage, if used for hydropower production, must be eventually replaced by water pumped back to the level of water intakes with a net loss in energy. The large fluctuations in releases to meet peak demand requirements often conflict with the recreation objective both on the reservoir surface and on the stream below the dam.

Table 7 contains a summary of information on the primary use of the storage behind the 49,500 dams in the Corps inventory. This table does not distinguish between single-purpose and multiple-purpose projects and does not reflect the extreme variation of reservoir use between various regions. The predominant use of reservoir storage in each major drainage area is shown in Appendix C.

[8]P.R. Vance and L.C. Bryan, "Hydro Power: Economic Comparisons," MITRE Technical Report MTR-3394, December 30, 1976, p 15.

Table 7

National Use of Existing Reservoir Storage

Primary Purpose	Number of Dams	Total Maximum Storage (Millions of Acre-Feet)
Irrigation	6,329	150.083
Hydroelectric	1,372	167.768
Flood Control	7,776	300.678
Navigation	187	125.355
Water Supply	7,279	267.187
Recreation	16,639	263.986
Debris Control	344	190.907
Farm Ponds	4,546	197.796
Other	4,779	111.456

The FPC estimate of hydropower potential at larger dams includes some consideration for competitive use of storage, but the Corps estimate for existing dams below 5,000 KW capacity assumes that all existing reservoir storage would be converted to hydropower storage and used to produce electricity. This would obviously create considerable economic disruption in many cases. For example, the Occoquan reservoir in Northern Virginia annually supplies 58 million gallons per day of water to Washington metropolitan area customers, yielding $12 million in gross revenues.[9] In the FPC inventory, this same dam, raised to provide a hydraulic head four times greater than now exists, would have a rated capacity of 17,500 KW capable of producing 47 million KWH of electricity per year. At current average household utility rates in Northern Virginia ($0.039/KWH)[10] the financial yield from this reservoir would be only $1.8 million. On the other hand, one of the current water problems in the West is the ability of electricity companies to outbid irrigators for scarce water supplies. In this case, although the transfer of water from irrigation to hydropower may be economically efficient, the economic impacts would be severe to the many small farmers in the region.

It is possible to estimate the magnitude of the reduction in estimated capacity caused by competitive demand for reservoir storage if it is assumed that the U.S.G.S. streamflow estimates already fully account for the effects of current reservoir operations and withdrawals. All average annual streamflow would thus be available for power production. Omitting the reservoir drawdown component from the flow used to calculate small dam hydropower potential results in a reduction of about 18 percent (9.3 million KW of capacity and 30 billion KWH of generation) to the national estimates.

[9]Telephone communication, Fairfax Water Authority, June 1977.
[10]Telephone communication, Virginia Electric Power Company, June 1977.

3. <u>Environmental Considerations</u>

The environmental implications of the development of hydropower resources must be viewed in terms of the overall quantitative relationship of hydropower to total electrical energy needs. It is evident that even the total development of hydropower resources at existing dams is not an alternative to the extensive development of other indigenous resources such as coal, natural gas, petroleum, geothermal energy and nuclear power. Hence, the effectiveness of hydropower development in preventing or mitigating the environmental consequences of fossil fuel or nuclear plants is limited.

Existing dams which have been in place a long time have become ecologically stable; i.e., both water and adjacent land flora and fauna have adjusted to the presence of the reservoir and the substitute ecologic network now depends on its existence. The best retrofit condition, from an ecologic point of view, would involve a simple rerouting of normal reservoir discharge through a turbine. This is identical to a "run-of-the-river" mode of operation.

However, the most economically efficient use of many hydropower dams would be for peak load power, where the reservoir is essentially the hydraulic equivalent of a storage battery which accumulates energy most of the time and is rapidly dumped during periods of peak energy demand. Most of the existing dams in the U.S. do not have sufficient storage for peak load operation and would have to be used in a "run-of-the-river" mode. But dams with peak power capability, if converted to such use, would be subject to frequent filling and drawdown of their reservoirs with attendant large variations in downstream flows which might cause serious environmental, ecologic, and aesthetic impacts.

The Corps analysis of small dams indicates that 19.6 million KW of capacity and 45.7 billion KWH of generation is attributed to dams which would probably be operated for peak load power. It can be assumed that at least the same percentage of potential for dams in the FPC inventory would also be for peak power production. Thus the environmental constraint may reduce the national estimates by as much as 24.8 million KW and 56.7 billion KWH of generation.

It may be that the environmental impacts of small-scale peak load hydropower plants are highly localized and relatively insignificant. However, more comprehensive environmental analysis, using data from existing small-scale hydropower installations, would be required before the economic and environmental trade-offs of peak power generation could be determined.

4. <u>Social Aspects</u>

An assessment of the social effects of water development decisions has become an integral part of the water resources planning process. The effects of a small-scale hydropower development program must take into account the impact on individual consumers of electricity, the community structure and order, and a concern for national social well-being.

Within the limited time and objectives of this study, it is only possible to determine some of the more obvious social ramifications of small-scale hydropower development. These include:

- possible conflicts associated with reallocating reservoir storage from any other purpose to hydropower. Such a change could shift the incidence of project benefits from one group to another and cause a possible redistribution of income in nearby communities.

- possible health and safety considerations. A local dam may be either more or less hazardous after conversion to hydropower, depending on the care with which renovation is undertaken. Some safety effects may also apply to downstream in-stream users (such as boaters or fishermen) due to changes in the operation of a dam, particularly if the dam is used for peak load power.

- possible effects on community cohesion. The decentralization effect caused by a shift from a large and remote steam-electric plant to a nearby hydropower dam may have a positive effect. Decentralization of energy resources would allow individual communities to have more control over electricity supplies. The energy crisis would be perceived as a problem which the community could collectively confront by establishing operating policies for its hydropower resources. This is especially true if reimbursement for power delivered outside the community is available.

- possible effects on attitudes toward energy conservation. Because small-scale hydropower is so susceptible to variations in rainfall and streamflow, dependence on a local hydropower plant would lead to increased sensitivity to the waste of electricity, especially during dry periods of the year.

- possible effects of the uneven reliability of small-scale hydropower. Inevitably, a power system based on a significant amount of small-scale hydropower will experience a shortfall due to short-term and long-term droughts. A serious hazard situation may be created if power shortages coincide with times of community crisis (say a major fire).

The effects listed above are only a few of the many social ramifications of small-scale hydropower development. It is a difficult task, but perhaps the most important one of all, to unravel the innumerable possible social and psychological consequences prior to a significant national effort to develop small-scale hydropower at existing dams.

5. Institutional and Legal Implications

Only 5,500 of the 49,500 dams in the United States are owned and operated by the Federal Government. The remainder are owned by state and local governments, by public and private utilities, by industries and private corporations, and by individuals. Each class of potential hydropower developer operates within a particular set of institutional constraints imposed by (1) regulatory agencies at all levels of government; (2) riparian or appropriation water laws; (3) individual, community, or corporate goals, values, beliefs, mores, and customs; (4) existing treaties, state constitutions, local charters, ordinances, and municipal by-laws; (5) a unique economic and financial environment; and (6) conflicts between short-range and long-range organizational and individual objectives.

Because such a large proportion of existing dams are owned by nonfederal interests, the role of the Federal Government in development of small-scale hydroelectric projects becomes supportive, consultative, and facilitative in nature, as opposed to the traditional federal role as the dominant institution in water resources development. The Federal Power Commission plans to streamline its license application procedure for small-scale hydropower plants to simplify the procedure and thereby reduce the time required to obtain a license. The Energy Research and Development Administration is initiating a research, development and demonstration program in small-scale hydropower development to alleviate some of the uncertainty of nonfederal interests toward the overall feasibility of such installations.

These are some of the necessary first steps toward developing an integrated system of Federal incentives and policies which encourage the private development of small-scale hydropower projects. Future actions must deal not only with the Federal sector, but also identify and alleviate the many nonfederal legal, regulatory, and financial barriers which could retard or prevent the timely development of small-scale hydroelectric potential at existing dams.

CHAPTER 3

RECOMMENDATIONS

Demonstration Studies

The principal conclusions of this study are that none of the identifiable constraints to the development of hydroelectric power at existing dams are insurmountable and that the national potential is of such significance to warrant the rapid selection and development of small-scale hydropower demonstration projects. Demonstration projects constitute the best means of developing the additional data needed to better assess the engineering and economic feasibility of a small-scale hydropower development program. At least a few of the demonstration projects should be at retired hydropower sites, since these dams offer the best opportunity to quickly and inexpensively construct prototype powerhouses and concentrate effort and funds on important technological considerations.

The FPC has provided the Corps with a list of 771 hydropower plants which have been retired from service since 1940. The largest of the plants, at sites which may be susceptible to rehabilitation, are:

Name	Listed Owner	River and State	Capacity (KW)
Riley Mill	International Paper	Androscoggin, Maine	5,400
Lowell	Merrimack Mfg Co.	Merrimack, Mass	5,150
Mechanicsville	No name listed	Hudson, New York	6,300
Jackson Bluff	Florida Power Corp	Oklicknee, Florida	8,800
Ozark	Empire Dist Elec Co.	Finley Creek, Mo.	7,200
Lower Dam	Twin City Rapid Tran.	Mississippi, Minn.	8,000
Nolickucky	No name listed	Nolickucky, Tenn.	10,640
Grace	Utah Power & Light	Bear, Utah	11,000
Lewistone	Wash Power & Light	Clearwater, Idaho	10,000
American River	Pacific Gas & Elec.	S Fk. American, Calif.	5,477

These are but a few of the many sites which could serve as demonstration projects for small-scale hydropower development. Additional study is needed to establish demonstration site criteria, select at least 50 sites with demonstration potential, and determine whether these sites would be available for demonstration purposes. The Corps of Engineers recommends the authorization and funding of such a study.

In addition to the demonstration program, a research program to develop small-scale hydropower planning, design, construction, and implementation techniques is needed. The suggested scope of such a program involves relatively low-intensity efforts addressed to as many different issues as possible in order to further define the magnitude and severity of the issues discussed in Chapter 2 and summarized below. Furthermore, the studies should be designed to provide results which can be adopted and used by local consulting firms, city engineering departments, and individual owners of small dams.

Review of Constraints and Suggested Approaches

Engineering Feasibility Factors

Issue 1: There is a need to further develop and refine small-scale hydropower turbine technology.

- Direct federal research and development funds to the basic study of low-head turbine design and small-scale package plants which can be tested in a selected number of demonstration projects.

- Direct federal R&D funds to the development of nonturbine based low-head hydropower technology.

Issue 2: There is a need to develop simplified hydrology, reservoir yield, and power plant capacity analysis techniques.

- Develop simplified hydrologic analysis and hydropower engineering techniques for use in designing small-scale hydropower facilities. Existing techniques need to be simplified because the economics of small-scale hydropower development will not support extensive and expensive engineering investigations at each potential site.

Issue 3: Many potential hydropower dams require major rehabilitation.

- Determine the likely extent and cost of the rehabilitation required for full scale implementation of a small-scale hydropower development program. The Corps of Engineers has recommended to the Congress that further funds be appropriated for the dam safety inspection program to identify and correct high hazard conditions which may result in loss of life or property. Such an inspection program could also provide some of the necessary data to determine the amount and cost of rehabilitation which would be required to retrofit any potential site with a hydropower plant. The relative deterioration of a dam should be included as a criterion for selection of demonstration projects so various rehabilitation techniques can be tested and cost comparisons can be performed.

Issue 4: The design of power transmission grids and switching systems becomes extremely complex when small-scale hydropower units are included in the network.

- Perform a state-of-the-art study to determine the most effective way to interface small-scale hydropower plants with existing and planned regional grids. A task force composed of representatives from federal agencies, utility consulting firms, and public or private utilities should be formed to define and direct research in this area.

Issue 5: <u>The relative economic efficiency and financial feasibility of small-scale hydropower versus alternative electrical generation techniques is unknown.</u>

- Develop data to determine the costs of retrofitting existing dams for hydropower production--especially for small dams.

- Conduct a short-term study of the relative economic efficiency of alternative electrical generation systems. In addition to the usual study of required capital outlays, annual variable costs, and expected annual average yield in kilowatt-hours and revenues, such a study should include:

  (a) the effects of present-price costing versus life-cycle costing on economic efficiency.

  (b) a net energy analysis of competitive systems. This technique attempts to measure the total energy required to construct equipment, produce fuels and operate and maintain physical plant versus the energy produced by each kind of facility.

Issue 6: <u>Diverting reservoir storage from current use to hydropower production could be inefficient and cause significant economic stress in many instances.</u>

- Review applicable value of water concepts developed by the National Water Commission and by a number of water resource institutions. These concepts could be combined with electricity values determined by present and forecasted market conditions to give a better understanding of the economic shifts, if any, which may occur from the development of small-scale hydropower.

Issue 7: <u>The ecologic impacts of peak load power production by small-scale hydropower plants are possibly significant:</u>

- Collect data on existing small-scale hydropower facilities to determine the character and magnitude of upstream and downstream ecologic impacts.

- Develop clearly defined standards for environmental review of proposed small-scale hydropower facilities.

- Direct federal efforts toward regional and basin-level studies of the possible environmental implications of small-scale hydropower development. Such studies would provide a framework for analysis of individual sites by state, local, and private interests.

Social Considerations

Issue 8: The social effects of a small-scale hydropower program are numerous, diffuse, and largely unknown.

- Conduct a full-scale technology assessment for the small-scale hydropower development program to identify potentially desirable and undesirable social effects at the individual, the community, and the national levels.

Issue 9: Institutional barriers may retard or prevent development of small-scale hydropower.

- An interagency task force should be organized to:

  (a) Conduct a study to identify and define institutional barriers due to existing federal law, regulatory processes, or agency policies.

  (b) Direct similar studies of state, local, and private sector barriers by funding studies of five states with significant small-scale hydropower potential.

APPENDIX A

HYDROPOWER ESTIMATION PROCEDURE FOR SMALL DAMS

The Corps' estimate of hydropower potential at existing dams with less than 5,000 KW capacity was performed using a methodology developed by the Corps' Institute for Water Resources. The methodology relies on existing data sources and, particularly, on the collective judgment and experience of Corps planners and engineers in each field office to derive power potential statistics for river basins within each District's boundaries. The derived estimate of potential is based on the rationale that:

(1) with general knowledge of streamflow amounts and variations; and

(2) with knowledge of the number and engineering characteristics of existing dams in a basin; and

(3) with the assumption that existing dams were designed rationally; an experienced engineer who is familiar with a local area can allocate dams throughout a basin such that an assumed distribution of dams on the average will approximate the actual distribution of existing dams. Then, the total hydropower potential of a basin based on an assumed distribution of dams will give a good approximation of the potential of the sum of the actual individual sites.

Three parameters are needed to calculate the power generated at a hydroelectric project: (1) hydraulic head on the turbine; (2) the amount of water flowing through the turbine; and (3) the efficiency of the turbine/generator system. These parameters are entered into the hydropower formula:

$$P = \frac{Qhe}{11.8}$$

where
- P = power production in kilowatts
- Q = flow through turbine in cubic feet per second
- h = hydraulic head on the turbine in feet
- e = efficiency
- 11.8 = a constant that accounts for the weight of the water, (62.5 lbs/ft^3) and the rate that work is performed (1 kilowatt = 737 ft-lb/sec)

The hydraulic head (h) is the difference in height between the water levels upstream and downstream of a dam minus the losses due to friction and other causes as the water passes through the project.[1] Both the upstream and downstream water levels will vary depending on the amount of water flowing into a reservoir and the amount of water discharged through the turbine during any given time interval. For this study, the maximum height of the dam, a characteristic measured during the Dam Safety Inventory, was used to estimate maximum potential hydraulic head.

[1] Hydraulic head is readily convertible to pressure (100 ft. of head x 62.5 $lbs/ft.^3 \div 144\ in^2/ft.^2 = 43.4$ psi).

The determination of Q, the flow of water through the turbine, normally requires a detailed hydrologic investigation using nearby river gauges which record yearly streamflow variation. Reliable Q (often associated with the firm capacity of a hydropower plant) depends on the relationship between streamflow and the amount of reservoir storage available to smooth out periods of high and low river flows. On a highly developed river such as the Columbia or the Mississippi, Q depends not only on the reservoir storage of a particular site, but also on the regulation and operation of a number of upstream dams as well.

The final element in the power equation is the efficiency (e). The efficiency of modern turbines and generators operating at design capacity is relatively high--on the order of 80-90 percent. For this study, a uniform efficiency of 0.9 was used for all hydropower calculations.

Streamflow characteristics at most of the 49,500 dams in the Corps' listing are not known and could not be determined in time to meet the 90-day deadline for this study. Instead, a method was derived which assessed average river flows for different types of streams in each river basin in the United States. Then the existing dams in each basin, grouped into low, medium, and high head and storage categories (see Table A-1) were allocated to the various river reaches in each basin by Corps field engineers and the maximum power potential of each category was computed. Finally, a set of correction factors derived by IWR were incorporated to estimate the expected capacity and electrical generation for each category of dams. The detailed procedure which was used to estimate hydropower potential is as follows:

(1) Each river basin was partitioned into four streamflow zones:

(a) intermittent = zero flow one to six months every year

(b) frequent zero = zero flow one week every year

(c) low-base flow = 0 - 50 percent of average discharge at the mouth of the basin

(d) high-base flow = 50 - 100 percent of average discharge at the mouth of the basin.

If there were extreme variations in river basin terrain, the streamflow zones were further subdivided into topographic zones. Then the drainage area of each streamflow (or streamflow-topographic) zone was estimated and the average drainage area for each type of stream in each zone was calculated.

(2) Generalized streamflow versus drainage area relationships were extracted from a U.S. Geological Survey study.[2] These relationships were used to estimate average annual Q in each streamflow (or streamflow/topographic) zone.

[2]U.S. Geological Survey, "A National Study of the Streamflow Data - Collection Program," 1971, 50 reports (one for each state).

(3) A Corps data file containing a listing of all existing dams and their engineering characteristics was sorted by river basin into 16 hydraulic head-reservoir storage categories.

Table A-1

Prototype Dam Characteristics

Hydraulic Head	Reservoir Storage
Low head (6-20 ft)	Low storage (15-100 acre-ft)
Moderate head (20-50 ft)	Moderate storage (100-1,000 acre-ft)
High head (50-100 ft)	High storage (1,000-10,000 acre-ft)
Head greater than 100 ft	Storage greater than 10,000 acre-ft

The number of dams in each category was counted and the average maximum head and maximum storage of the dams in each category was calculated. The Corps analysis of small-scale hydropower potential was limited to the nine categories with head less than 100 ft or storage less than 10,000 acre-ft.

(4) Each category of dams (called prototype dams) was allocated to one or more streamflow (or streamflow-topographic) zones based on the size of the drainage area, the quantity of streamflow, the configuration of the river basin and its valleys, and the prototype's average head and storage characteristics. It was assumed that all of the individual existing small dams in a basin were rationally sited and were designed to conform to site conditions. The resulting distribution of prototype dams, on the average, approximates the distribution of existing dams and collectively exhibits similar hydropower production potential.

(5) The hydropower potential of each prototype dam was calculated. Flow through the turbine is computed as average streamflow plus the release of all reservoir storage during one week; hydraulic head is set equal to maximum height of dam; and efficiency is assumed to be 0.9. The resulting maximum power potential for each prototype is multiplied by the number of dams in this category and then summed across prototypes to give the maximum power potential for each basin.

(6) Power potential is converted to an estimate of actual energy potential by multiplying by a factor, called the continuous power factor, which is a measure of the dependability of river flows and the regulation ability of a reservoir. Dams on intermittent streams with small reservoir storage will produce power for only short periods of time each year and have small continuous power factors. The opposite is true of high storage

dams on continuous discharge streams. Example continuous power factors used in the analysis are listed below:

Table A-2

Continuous Flow Factors

Streamflow Zone	Prototype Characteristic	Continuous Power Factor
Intermittent	Low Storage	.10
Frequent Zero Flow	Low Storage	.20
	Moderate Storage	.30
Low Base Flow	Low Storage	.20
	Moderate Storage	.30
	High Storage	.50
High Base Flow	Low Storage	.40
	Moderate Storage	.60
	High Storage	.80

(7) Finally, the installed or nameplate capacity of each prototype dam is determined by multiplying the energy potential by a plant factor. The plant factor is also dependent on the ability of a reservoir to regulate streamflows. For small storage dams, streamflow must almost immediately be passed through a turbine to avoid overtopping of the dam. Thus, the dam would be operated as a "run-of-the-river" power producer, and the turbine design would be closely matched to average daily streamflow (plant factor = 1.0). On the other hand, a large storage dam would likely be operated to produce high value peak load power. Thus, daily average flows would be passed through the turbine during a 3- or 4-hour period and the turbine should be significantly larger. Example plant factors used for this analysis are listed in Table A-3.

(8) To compute electricity produced during one year in kilowatt-hours, energy potential is multiplied by 8,760 hours. Since the energy potential already includes an adjustment for the proportion of time the dam would be producing energy, the result is electricity yield during a typical year.

Table A-3

Plant Factors

Streamflow Zone	Prototype Dam Characteristic	Plant Factor
Intermittent	Low Storage	1.0
Frequent Zero	Low Storage	1.0
	Moderate Storage	1.67
Low Base Flow	Low Storage	1.1
	Moderate Storage	2.0
	High Storage	10.0
High Base Flow	Low Storage	1.11
	Moderate Storage	1.67
	High Storage	4.0

APPENDIX B

REGIONAL STATISTICS

Statistics on the maximum hydropower potential at existing dams for each river basin in each major river region of the U.S. are presented in this appendix. It should be recognized that there is a larger potential for error in the estimates for each basin than for the nation or each region, since the estimation methodology relies on the tendency for high and low basin estimates to cancel out. Each regional summary also includes tabulations of several of the engineering characteristics of the dams in each region.

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

NEW ENGLAND: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity)						Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
			Rehabilitation Potential (9%)		Hydro Expansion Potential		Hydro Installation Potential					
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
St. John-St. Croix	29.9	114.9	2.7	10.3	0.2	1.0	0	0	10.2	56	12.3	67.3
Penobscot	152.6	838.8	13.7	75.5	3.6	23.7	0	0	93.7	608	111.1	707.2
Kennebac-Androscoggin	355.8	1,809.6	32.0	162.9	26.7	98.7	34.0	116.0	341.0	2,129	433.1	2,506.6
Saco	46.4	266.3	4.2	24.0	25.6	104.5	0	0	83.9	410	113.6	538.5
Merrimack	67.8	270.1	6.1	24.3	50.2	95.0	72.0	141.9	436.8	1,985	565.1	2,246.2
Mass.-R.I. Coastal	1.6	4.3	0.1	0.4	0	0	0	0	244.6	1,058	244.8	1,058.4
Long Island Sound	111.7	321.9	10.0	29.0	0	0	13.0	40.0	314.8	1,393	337.8	1,462.0
Connecticut	655.9	2,092.9	59.0	188.3	81.2	179.0	104.5	219.0	905.5	4,038	1,150.2	4,624.3
St. Francis	0	0	0	0	0	0	0	0	1.8	8	1.8	8.0
	1,426.7	5,718.8	127.3	514.7	187.5	501.9	223.5	516.9	2,432.3	11,685	2,970.0	13,218.5

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	850	860	231	59
20-49	193	324	181	21
50-99	17	28	43	15
More than 100	6	4	10	24

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	1,021	157	233	0
Rockfill	195	27	8	0
Gravity	630	217	123	0
Buttress	109	7	7	0
Arch	6	1	0	0
Multi-Arch	0	0	0	0
Other	114	10	1	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

MID-ATLANTIC: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity)						Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
			Rehabilitation Potential (9%)		Hydro Expansion Potential		Hydro Installation Potential					
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
Richelieu	0	0	0	0	0	0	0	0	1,211.5	3,730	1,211.5	3,730.0
Upper Hudson	379.7	1,670.8	34.2	150.4	187.0	267.7	6.4	20.0	1,883.4	5,628	3,660.6	9,675.1
Lower Hudson									1,549.6	3,609		
Delaware	69.3	157.8	6.2	13.3	40.0	77.6	170.6	392.0	152.0	245	368.8	727.9
Susquehanna	827.9	3,307.4	74.5	297.7	338.0	1,600.0	246.3	203.0	413.4	721	1,072.2	2,821.7
Upper Chesapeake Bay	13.4	65.1	1.2	5.9	0	0	97.5	177.0	5.6	25	217.9	637.9
Potomac									113.6	430		
Lower Chesapeake Bay	30.4	112.8	2.7	10.2	0	0	0	0	250.6	891	253.3	901.2
	1,320.7	5,313.9	118.8	477.5	565.0	1,945.3	520.8	792.0	5,580.0	15,279	6,784.4	18,493.8

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	608	741	143	26
20-49	439	459	168	30
50-99	71	95	76	46
More than 100	11	3	17	37

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	713	490	981	0
Rockfill	34	8	19	0
Gravity	346	106	72	0
Buttress	15	6	4	0
Arch	7	6	3	0
Multi-Arch	2	0	0	0
Other	110	24	27	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

SOUTH ATLANTIC GULF: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity)						Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
			Rehabilitation Potential (9%)		Hydro Expansion Potential		Hydro Installation Potential					
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
Roanoke	855.3	1,286.6	77.0	115.8	855.3	1,286.6	0	0	17.6	26	949.9	1,428.4
Tar-Neuse	1.6	5.7	0.1	0.5	1.6	5.7	0	0	19.4	34	21.1	40.2
Cape Fear	0.8	2.1	0.1	0.2	0.8	2.1	10.0	21.9	83.0	103	93.9	127.2
Pee Dee	311.3	1,262.0	28.0	113.6	0	0	0	0	384.4	1,542	412.4	1,655.6
Santee-Edisto	1,255.8	2,649.4	113.0	238.4	47.4	667.7	0	0	618.7	1,716	779.1	2,622.1
Savannah-Ogeechee	894.1	1,901.4	80.5	171.1	66.0	100.0	0	0	1,188.9	10,415	1,335.4	10,686.1
Altamaha-St. Marks	63.4	247.8	5.7	22.3	0	0	19.0	99.0	455.4	3,989	480.1	4,110.3
St. Johns	0	0	0	0	0	0	0	0	1.0	12	1.0	12.0
Southern Florida	0	0	0	0	0	0	0	0	0	0	0	0
Tampa Bay	0	0	0	0	0	0	0	0	3.3	44	3.3	44.0
Suwannee	0	0	0	0	0	0	0	0	5.1	26	5.1	26.0
Ochlockonee	0	0	0	0	0	0	0	0	0	0	0	0
Appalachicola	545.2	2,067.4	49.1	186.1	545.2	2,067.4	267.2	334.4	202.9	1,099	1,064.4	3,686.9
St. Josephs-Perdido	7.6	23.8	0.7	2.1	7.6	23.8	0	0	213.0	489	221.3	514.9
Alabama	1,575.2	4,539.8	141.8	408.6	1,575.2	4,539.8	527.1	547.0	745.8	1,282	2,989.9	6,777.4
Tombigbee	242.6	535.0	21.8	48.2	242.6	535.0	51.0	253	165.2	735	480.6	1,571.2
Pascagoula	0	0	0	0	0	0	0	0	47.6	143	47.6	143.0
Pearl	0	0	0	0	0	0	0	0	93.0	190	93.0	190.0
	5,752.9	14,521.0	517.8	1,306.9	3,341.7	9,228.1	874.3	1,255.3	4,244.3	21,845	8,978.1	33,635.3

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	2,963	1,547	98	67
20-49	661	1,111	201	74
50-99	14	51	40	59
More than 100	1	0	3	36

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	436	1,822	4,257	0
Rockfill	7	3	9	0
Gravity	88	23	27	0
Buttress	14	5	1	0
Arch	23	8	4	0
Multi-Arch	2	0	0	0
Other	49	52	96	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

GREAT LAKES: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity): Rehabilitation Potential (9%)		Large Dam Potential: Hydro Expansion Potential		Large Dam Potential: Hydro Installation Potential		Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
Western Lake Superior	128.2	625.9	11.5	56.3	0	0	0	0	185.2	579	292.0	777
Southern Lake Superior									95.3	142		
Northwest Lake Michigan	298.3	1,216.4	26.8	109.5	9.5	41.0	0	0	61.4	1,154	256.4	1,532
Southwest Lake Michigan									74.6	82		
Southeast Lake Michigan									44.4	77		
Northeast Lake Michigan									39.7	68		
Northwest Lake Huron	120.6	659.7	10.9	59.4	2.0	7.0	0	0	44.4	56	73.2	192
Southwest Lake Huron									12.0	50		
St. Clair-Detroit									3.9	20		
Western Lake Erie	2.6	11.3	0.2	1.0	0	0	0	0	69.8	108	75.3	135
Southern Lake Erie									4.0	20		
Eastern Lake Erie									1.3	6		
Southwest Lake Ontario	3,458.5	22,241.0	311.3	2,001.7	241.2	530.2	142.6	580.5	0	0	702.8	3,173
Southeast Lake Ontario									0	0		
Northeast Lake Ontario-St. Lawrence									7.7	61		
	4,008.2	24,754.3	360.7	2,227.9	252.7	578.2	142.6	580.5	643.7	2,423	1,400	5,809

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet): 0-99	100-999	1,000-9,999	More than 10,000
0-19	362	368	106	37
20-49	86	125	93	36
50-99	2	3	11	12
More than 100	0	1	1	1

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed: Before 1931	1931-1955	1956 to date	Unknown
Earth	325	220	330	0
Rockfill	6	0	1	0
Gravity	239	78	31	0
Buttress	3	0	0	0
Arch	0	2	0	0
Multi-Arch	1	3	0	0
Other	1	2	2	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

OHIO RIVER: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity)						Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
			Rehabilitation Potential (9%)		Hydro Expansion Potential		Hydro Installation Potential					
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
Allegheny	54.9	97.9	4.9	8.8	0	0	0	0	57.6	61	62.5	69.8
Monongahela	70.4	152.8	6.3	13.8	0	0	465	173	63.5	74	534.8	260.8
Pittsburgh-Wheeling-Beaver	0.1	0.5	–	–	0	0	0	0	172.9	173	172.9	173
Muskingum	259.6	1,126.3	23.4	101.4	0	0	270	877	233.1	260	1,546.0	2,239.4
Kanawha									314.7	315		
Scioto									77.1	90		
Portsm.-L.Kanawha-B.Sandy									627.7	596		
Great Miami	2.5	9.3	0.2	0.8	0	0	0	0	22.6	55	37.0	108.8
Cinc-Little Miami									14.2	53		
Licking-Kentucky	30.3	75.2	2.7	6.8	0	0	9.4	53	28.7	90	40.8	150
Louisville-Salt			0	0	0	0	0	0	7.1	27	7.1	27
White-Patoka	17.7	60.0	1.6	5.4	0	0	0	0	54.2	146	90.3	274.4
Wabash									34.5	123		
Cumberland	884.9	3,095.0	79.6	278.6	0	0	0	0	101.3	625	180.9	903
Evansville-Green			0	0	0	0	0	0	64.3	161	64.3	161
Ohio Main Stream	145.1	888.0	13.6	79.9	19.2	100	670.1	3,577			702.9	3,757
	1,465.5	5,505	132.3	495.5	19.2	100	1,414.5	4,680	1,873.5	2,849	3,439.5	8,124

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	301	150	25	5
20-49	1,056	697	138	33
50-99	82	117	91	43
More than 100	30	34	13	46

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	190	778	1,559	0
Rockfill	8	5	31	0
Gravity	54	46	28	0
Buttress	0	1	0	0
Arch	1	0	0	0
Multi-Arch	1	0	0	0
Other	37	31	93	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

TENNESSEE RIVER: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity)						Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
			Rehabilitation Potential (9%)		Hydro Expansion Potential		Hydro Installation Potential					
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
Upper Tennessee	3,658.4	16,111.5	329.3	1,450	30.1	139	0	0	35.1	185	434.3	1,960
Tenn-Hiwassee-Sequatchie									8.2	47		
Tenn-Elk									23.8	105		
Lower Tennessee									7.8	34		
	3,658.4	16,111.5	329.3	1,450	30.1	139	0	0	74.9	371	434.3	1,960

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	111	55	2	0
20-49	79	105	25	0
50-99	7	13	15	10
More than 100	0	4	3	30

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	14	85	265	2
Rockfill	2	11	5	0
Gravity	15	24	10	0
Buttress	3	2	0	0
Arch	9	4	0	0
Multi-Arch	1	0	0	0
Other	3	2	2	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

UPPER MISSISSIPPI: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity)						Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
			Rehabilitation Potential (9%)		Hydro Expansion Potential		Hydro Installation Potential					
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
Minnesota	1.0	2.9	0.1	0.3	0	0	0	0	83.4	82	83.5	82.3
Mississippi Headwaters	4.6	22.5	0.4	2.0	0	0	0	0	2,884.1	5,183	2,884.5	5,185.0
St. Croix	31.6	150.9	2.8	13.6	0	0	0	0	44.9	196	47.7	209.6
Chippewa	161.5	672.5	14.5	60.5	58.9	150.0	0	0	57.0	131	130.4	341.5
Mississippi-Black-Root	7.0	24.7	0.6	2.2	2.2	4.0	0	0	23.9	108	26.7	114.2
Wisconsin	148.3	770.7	13.4	69.4	2.8	5.6	0	0	593.9	714	610.1	789.0
Miss-Maquoketa-Plum	1.2	5.0	0.1	0.4					0.9	4	1.0	4.4
Rock	5.2	26.0	0.5	2.3	0	0	6.8	37.0	31.9	124	39.2	163.3
Des Moines	3.0	11.0	0.3	1.0	0	0	17.2	103.6	31.7	148	49.2	252.6
Miss-Iowa-Quad	1.5	3.6	0.1	0.3	0	0	0	0	514.5	1,824	514.6	1,824.3
Miss-Salt-Quincy	0	0	0	0	0	0	0	0	6.5	36	6.5	36.0
Upper and Lower Illinois	22.4	93.8	2.0	8.4	0	0	69.6	368.0	66.6	230	138.2	606.4
Miss-Kaskaskin-St Louis	0	0	0	0	0	0	0	0	39.1	211	39.1	211.0
Mississippi Main Stream	194.0	1,222.7	17.5	110.0	16.0	100.9	105.1	568.6			138.6	779.5
	581.3	3,006.3	52.3	270.4	79.9	260.5	198.7	1,077.2	4,378.4	8,991	4,709.3	10,599.1

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	476	387	190	91
20-49	1,256	584	117	53
50-99	15	68	59	29
More than 100	0	2	4	1

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	146	388	2,071	0
Rockfill	4	5	12	0
Gravity	249	323	85	0
Buttress	2	3	1	0
Arch	2	1	0	0
Multi-Arch	1	0	0	0
Other	5	19	14	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

LOWER MISSISSIPPI: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity)						Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
			Rehabilitation Potential (9%)		Hydro Expansion Potential		Hydro Installation Potential					
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
Miss-Hatchee	0	0	0	0	0	0	18.0	83.0	514.9	2,001	532.9	2,084
Miss-St. Francis	0	0	0	0	0	0	7.5	21.0	1,999.7	5,518	2,007.2	5,539
Miss-Yazoo	0	0	0	0	0	0	0	0	21.6	186	21.6	186
Quachita	205.8	423.5	18.5	38.1	87.7	135.6	0	0	6.4	53	112.6	227
Miss-Tensas	0	0	0	0	0	0	0	0	1.5	2	1.5	2
Miss-Big Black	0	0	0	0	0	0	0	0	12.3	108	12.3	108
Miss-Lake Maurepas	0	0	0	0	0	0	0	0	24.0	232	24.0	232
Lousiana Coastal	0	0	0	0	0	0	0	0	1.0	8	1.0	8
Miss Delta	0	0	0	0	0	0	0	0	0.2	2	0.2	2
	205.8	423.5	18.5	38.1	87.7	135.6	25.5	104.0	2,581.6	8,110	2,713.3	8,388

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	1,131	585	80	6
20-49	371	293	45	23
50-99	3	3	9	10
More than 100	0	0	0	6

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	38	691	1,790	0
Rockfill	2	8	9	0
Gravity	4	3	9	0
Buttress	0	0	1	0
Arch	1	0	0	0
Multi-Arch	0	0	0	0
Other	2	4	1	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

HUDSON BAY: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity)						Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
			Rehabilitation Potential (9%)		Hydro Expansion Potential		Hydro Installation Potential					
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
Souris	4.0	21.3	0.4	1.9	0	0	0	0	0.2	0	48.4	67
Red									47.8	65		
Rainy	9.6	46.7	0.9	4.2	0	0	0	0	3.1	7	4.0	11
	13.6	68.0	1.3	6.1	0	0	0	0	51.1	72	52.4	78

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	40	90	49	43
20-49	19	31	16	3
50-99	5	5	3	0
More than 100	0	0	0	0

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	0	97	96	0
Rockfill	0	1	0	0
Gravity	22	55	4	0
Buttress	0	2	0	0
Arch	0	0	0	0
Multi-Arch	0	0	0	0
Other	2	16	9	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

MISSOURI: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity)						Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
			Rehabilitation Potential (9%)		Hydro Expansion Potential		Hydro Installation Potential					
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
St. Mary	0	0	0	0	0	0	0	0	0	0	0	0
Missouri Headwaters	9.0	50.0	0.8	4.5	9.0	50.0	12.0	64.0	2.6	11	24.4	129.5
Missouri-Marias	463.8	3,070.0	41.7	276.3	377.0	1,425.7	11.0	41.0	14.9	47	458.6	1,821.0
Missouri-Musselshell									11.8	17		
Milk									1.9	12		
Missouri-Poplar									0.3	2		
Upper Yellowstone	286.6	1,226.6	25.8	110.4	0	0	279.3	491.0	3.8	5	335.6	651.4
Bighorn									19.5	28		
Tongue-Powder									2.9	13		
Lower Yellowstone									4.3	4		
Missouri-Little Missouri	0	0	0	0	0	0	0	0	6.5	9	6.5	9.0
Cheyenne	8.4	33.0	0.8	3.0	0	0	10.0	33.0	2.2	14	13.0	50.0
Missouri-Oahe	1,463.0	6,047.5	131.7	544.3	565.3	3,032.5	0	0	2.1	16	699.1	3,592.8
Missouri-White	320.2	1,680.1	2[illegible].8	151.2	0	0	0	0	9.3	22	38.1	173.2
Niobrara	103.9	710.2	9.3	63.9	2.6	11.0	0	0	0.2	2	12.1	76.9
James	0	0	0	0	0	0	0	0	1.5	10	1.5	10.0
Missouri-Big Sioux	0	0	0	0	0	0	0	0	8.1	8	8.1	8.0
North Platte	489.0	1,948.1	44.0	175.3	56.7	53.3	90.6	192.5	2.6	11	323.6	615.1
South Platte									114.9	157		
Loup									8.2	9		
Platte									3.7	2		
Elkhorn									2.9	15		

Basin Name	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity): Rehabilitation Potential (9%)		Large Dam Potential: Hydro Expansion Potential		Large Dam Potential: Hydro Installation Potential		Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
Missouri-Sioux City-Omaha	0	0	0	0	0	0	0	0	2.2	13	2.2	13
Missouri-Nemaha-Nodaway	0	0	0	0	0	0	0	0	1.8	16	1.8	16
Republican									6.8	8		
Smoky Hill	3.9	16.3	0.3	1.5	0	0	83.0	285.0	1.4	9	93.5	320.5
Kansas									2.0	77		
Grand-Charitan	0	0	0	0	0	0	0	0	3.9	34	3.9	34.0
Osage-Gasconade	221.8	511.7	20.0	46.1	26.5	59.7	0	0	4.6	40	51.1	145.8
Missouri-Kansas City	0	0	0	0	0	0	0	0	3.3	29	3.3	29.0
	3,369.6	15,293.5	303.2	1,376.5	1,037.1	4,632.2	485.9	1,106.5	250.2	580	2,076.4	7,695.2

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	2,941	864	69	12
20-49	5,562	1,838	252	50
50-99	61	81	105	54
More than 100	8	8	12	69

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	959	3,766	7,120	0
Rockfill	8	12	5	0
Gravity	25	23	10	0
Buttress	4	2	2	0
Arch	13	4	5	0
Multi-Arch	0	0	0	0
Other	11	8	10	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

ARKANSAS-WHITE-RED: MAJOR DRAINAGE

Basin Name	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity): Rehabilitation Potential (9%)		Large Dam Potential: Hydro Expansion Potential		Large Dam Potential: Hydro Installation Potential		Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
White	834.0	1,897.0	7.1	170.7	109.0	171.8	28.0	47.0	362.7	1,091	574.8	1,480.5
Upper Arkansas	416.7	1,069.1	37.5	96.2	22.5	27.0	0	0	45.1	189	386.4	752.2
Arkansas in Kansas									15.0	47		
Upper Cimarron									10.8	21		
Lower Cimarron									30.7	46		
Arkansas Keystone									17.6	54		
Verdigris-Neosho									207.2	272		
Upper Canadian	518.0	1,806.3	46.6	162.6	0	0	217.5	274.8	1.5	10	1,250.6	3,151.4
Canadian in Texas									55.1	157		
Lower Canadian									55.7	139		
Lower Arkansas									874.2	2,408		
Red River Headwaters	70.0	247.0	6.3	22.2	105.0	70.0	0	0	19.5	171	392.4	1,028.2
Red-Washita									261.6	765		
Lower Red	0	0	0	0	0	0	0	0	360.9	1,155	360.9	1,155.0
	1,838.7	5,019.4	165.5	451.7	236.5	268.8	245.5	321.8	2,317.6	6,525	2,965.1	7,567.3

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet): 0-99	100-999	1,000-9,999	More than 10,000
0-19	1,270	385	35	7
20-49	1,514	1,386	150	33
50-99	28	106	83	70
More than 100	3	3	2	28

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed: Before 1931	1931-1955	1956 to date	Unknown
Earth	276	1,138	3,570	0
Rockfill	5	15	15	0
Gravity	15	23	23	0
Buttress	1	4	0	0
Arch	3	3	0	0
Multi-Arch	0	1	0	0
Other	2	8	2	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

TEXAS-GULF: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity)						Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
			Rehabilitation Potential (9%)		Hydro Expansion Potential		Hydro Installation Potential					
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
Sabine-Neches	133.0	331.1	12.0	29.8	0	0	2.9	22.5	41.4	130	56.3	183
Upper-Lower Trinity	0	0	0	0	0	0	0	0	69.3	199	69.3	199
Brazos	52.5	163.2	4.7	14.7	11.3	6.0	19.0	30.0	251.4	474	286.4	525
Colorado River of Texas	191.0	525.0	17.2	47.3	0	0	0	0	58.0	194	75.2	241
Guadalupe-San Antonio	16.3	54.7	1.5	4.9	0	0	20.8	8.4	30.5	58	52.1	71
Nueces-Frio	0	0	0	0	0	0	0	0	9.9	40	9.9	40
	392.8	1,074.0	35.4	96.7	11.3	6.0	42.7	60.9	460.5	1,095	549.2	1,259

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	636	409	52	3
20-49	846	1,251	80	9
50-99	24	122	24	56
More than 100	0	0	0	24

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	166	582	2,689	0
Rockfill	5	1	1	0
Gravity	30	12	15	0
Buttress	15	5	9	0
Arch	0	0	0	0
Multi-Arch	0	0	0	0
Other	3	1	2	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

RIO GRANDE: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity)						Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
			Rehabilitation Potential (9%)		Hydro Expansion Potential		Hydro Installation Potential					
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
Rio Grande Headwaters	0	0	0	0	0	0	50.0	155.0	67.8	244	140.5	548.0
North Rio Grande									10.3	90		
Rio Grande Mimbres									6.7	26		
Rio Grande-Big Bend									5.7	33		
Rio Grande Closed	65.4	233.5	5.9	21.0	20.5	49.5	80.0	156.0	0.2	1	200.4	621.5
Upper Pecos									4.1	18		
Lower Pecos									9.2	33		
Rio Grande-Amistad									26.1	150		
Lower Rio Grande									54.4	193		
	65.4	233.5	5.9	21.0	20.5	49.5	130.0	311.0	184.5	788	340.9	1,169.5

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	115	88	23	1
20-49	109	93	18	2
50-99	20	20	8	11
More than 100	3	1	4	10

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	66	135	299	0
Rockfill	1	1	2	0
Gravity	10	3	1	0
Buttress	1	0	0	0
Arch	4	0	0	0
Multi-Arch	0	0	0	0
Other	0	2	1	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

GREAT BASIN: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity)						Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
			Rehabilitation Potential (9%)		Hydro Expansion Potential		Hydro Installation Potential					
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
Bear Great Salt Lake	164.8	551.9	14.8	49.7	0	0	0	0	4.1 29.7	36 37	48.6	122.7
Sevier Lake	352.9	1,342.2	31.8	120.8	0	0	0	0	5.9	32	37.7	152.8
Humboldt	0	0	0	0	0	0	0	0	6.5	31	6.5	31.0
Central Lahontan	11.9	82.0	1.1	7.4	0.8	1.0	0	0	39.2	43	41.1	51.4
Tonopah Desert	0	0	0	0	0	0	0	0	0	0	0	0
	529.6	1,976.1	47.7	177.9	0.8	1.0	0	0	85.4	179	133.9	357.9

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	60	85	16	1
20-49	34	105	47	16
50-99	3	14	27	13
More than 100	0	2	4	9

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	156	128	125	0
Rockfill	4	4	0	0
Gravity	11	1	0	0
Buttress	0	1	0	0
Arch	2	1	2	0
Multi-Arch	1	0	0	0
Other	0	0	0	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

UPPER COLORADO: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity)						Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
			Rehabilitation Potential (9%)		Hydro Expansion Potential		Hydro Installation Potential					
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
Upper Green									3.8	17		
Yampa-White	120.2	684.2	10.8	61.6	0.1	0.1	0	0	11.9	54	48.5	173.7
Lower Green									21.9	41		
Gunnison	181.8	722.2	16.4	65.0	15.5	80.0	0	0	6.0	32	37.9	177.0
Colorado Headwaters	41.5	171.6	3.7	15.4	0	0	0	0	300.2	304	303.9	319.4
Colorado-Delores	3.6	10.8	0.3	1.0	0	0	0	0	6.4	29	6.7	30.0
Upper San Juan	12.4	45.1	1.1	4.0	0	0	24	49	75.0	76	139.5	169.0
Colorado-San Juan									39.4	40		
	359.5	1,633.9	32.3	147.0	15.6	80.1	24	49	464.6	593	536.5	869.1

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	189	179	26	4
20-49	168	256	62	7
50-99	8	27	35	13
More than 100	1	1	8	35

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	327	332	338	0
Rockfill	3	2	5	0
Gravity	3	1	0	0
Buttress	0	0	0	0
Arch	1	1	4	0
Multi-Arch	0	0	0	0
Other	0	2	0	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

LOWER COLORADO: MAJOR DRAINAGE

<table>
<tr><th rowspan="2">Basin Name</th><th colspan="2" rowspan="2">Existing Hydropower Production Facilities</th><th colspan="6">Large Dam Potential (Greater than 5,000 KW Capacity)</th><th colspan="2" rowspan="2">Small Dam Potential (Less than 5,000 KW)</th><th colspan="2" rowspan="2">Total Basin Potential</th></tr>
<tr><th colspan="2">Rehabilitation Potential (9%)</th><th colspan="2">Hydro Expansion Potential</th><th colspan="2">Hydro Installation Potential</th></tr>
<tr><th></th><th>Capacity (MW)</th><th>Output (10^6KWH)</th><th>Capacity (MW)</th><th>Output (10^6KWH)</th><th>Capacity (MW)</th><th>Output (10^6KWH)</th><th>Capacity (MW)</th><th>Output (10^6KWH)</th><th>Capacity (MW)</th><th>Output (10^6KWH)</th><th>Capacity (MW)</th><th>Output (10^6KWH)</th></tr>
<tr><td>Little Colorado</td><td>2.9</td><td>7.3</td><td>0.3</td><td>0.7</td><td>0</td><td>0</td><td>0</td><td>0</td><td rowspan="3">87.3</td><td rowspan="3">526</td><td rowspan="3">402.8</td><td rowspan="3">1,394.3</td></tr>
<tr><td>Upper Gila
Gila-San Pedro
Gila-Salt</td><td>185.6</td><td>479.8</td><td>16.7</td><td>43.2</td><td>0</td><td>0</td><td>32.6</td><td>172</td></tr>
<tr><td>Colorado-Lake Mead
Colorado-Lake Mojave</td><td>2,658.4</td><td>10,053.6</td><td>239.3</td><td>535.4</td><td>0</td><td>0</td><td>26.6</td><td>117</td></tr>
<tr><td></td><td>2,846.9</td><td>10,540.7</td><td>256.3</td><td>579.3</td><td>0</td><td>0</td><td>59.2</td><td>289</td><td>87.3</td><td>526</td><td>402.8</td><td>1,394.3</td></tr>
</table>

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet) 0-99	100-999	1,000-9,999	More than 10,000
0-19	60	35	8	1
20-49	111	81	32	5
50-99	9	16	23	5
More than 100	24	2	6	14

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed: Before 1931	1931-1955	1956 to date	Unknown
Earth	47	132	197	0
Rockfill	5	1	6	0
Gravity	10	4	1	0
Buttress	0	1	0	0
Arch	3	12	3	0
Multi-Arch	5	1	0	0
Other	4	0	0	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

COLUMBIA-NORTH PACIFIC: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity): Rehabilitation Potential (9%)		Large Dam Potential: Hydro Expansion Potential		Large Dam Potential: Hydro Installation Potential		Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
Kootenai	216.9	467.0	19.5	42.0	630.0	1,287.0	0	0	0.6	2	650.1	1,331.0
Pend Oreille	654.2	4,295.8	58.9	386.6	275.5	425.0	0.4	60.4	12.5	57	347.3	929.0
Spokane	146.4	1,012.0	13.2	91.1	50.0	158.0	0	0	42.3	42	105.5	291.1
Yakima	34.4	182.1	3.1	16.4	0	0	24.9	160.0	11.1	10	39.1	186.4
Upper Snake	3,586.4	19,029.3	322.8	1,712.6	538.0	477.5	187.2	869.0	6.1	28	1,186.0	3,528.1
Middle Snake									111.2	405		
Salmon									5.4	20		
Lower Snake									15.3	16		
Upper Columbia	15,187.1	91,381.6	1,366.8	8,224.3	8,456.8	11,536.0	114.7	501.0	25.9	30	10,164.9	20,795.3
Middle Columbia									45.6	170		
Lower Columbia									155.1	334		
Deschuttes	357.3	1,357.6	32.2	122.2	0	0	0	0	67.6	243	99.8	365.2
Willamette	696.3	2,847.6	62.7	256.3	0	0	128.5	556.0	102.3	448	293.5	1,260.3
Puget Sound	1,212.6	5,107.4	109.1	459.7	731.1	981.9	152.6	781.0	18.0	84	1,010.8	2,306.6
Washington Coastal	0	0	0	0	0	0	20.0	22.0	1.3	6	21.3	28.0
Oregon Coastal	250.8	1,501.9	22.6	135.2	0	0	0	0	122.3	536	144.9	671.2
Oregon Closed	0	0	0	0	0	0	0	0	14.2	64	14.2	64.0
	22,342.4	127,182.3	2,010.9	11,446.4	10,681.4	14,865.4	628.3	2,949.4	756.8	2,495	14,077.4	31,756.2

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	214	305	63	18
20-49	144	243	87	34
50-99	9	50	52	39
More than 100	2	6	12	86

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	265	351	524	0
Rockfill	24	11	19	0
Gravity	40	35	23	0
Buttress	2	7	0	0
Arch	18	10	6	0
Multi-Arch	2	0	1	0
Other	18	5	5	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

CALIFORNIA-SOUTH PACIFIC: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity)						Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
			Rehabilitation Potential (9%)		Hydro Expansion Potential		Hydro Installation Potential					
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
North Coastal	265.6	1,292.8	23.9	116.3	0	0	116	258.0			139.9	374.3
Sacramento	4,409.3	19,675.5	396.8	1,770.8	488.0	1,378.7	114	327.5			998.8	3,477.0
Tulare	386.6	1,920.2	34.8	172.8	200.5	482.0	10	40.0			245.3	694.8
San Joaquin	1,583.2	8,914.9	142.5	802.3	221.5	1,013.0	6	30.0	Not		370.0	1,845.3
Delta Central Sierra	0	0	0	0	0	0	0	0	Available		0	0
San Francisco Bay	0	0	0	0	0	0	0	0			0	0
Central Coastal	0	0	0	0	0	0	0	0			0	0
South Coastal	252.3	981.3	22.7	88.3	59.8	390.0	268	1,649			350.5	2,127.3
South Lahontan	0	0	0	0	0	0	0	0			0	0
Colorado Desert	152.9	615.8	13.8	55.4	0	0	0	0			13.8	55.4
	7,049.9	33,400.5	634.5	3,005.9	969.8	3,263.7	514	2,304.5			2,118.3	8,574.1

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	90	151	52	17
20-49	181	251	71	21
50-99	51	90	70	32
More than 100	9	17	41	143

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	293	279	396	0
Rockfill	34	8	14	0
Gravity	48	34	22	0
Buttress	2	1	0	0
Arch	43	13	13	0
Multi-Arch	16	1	0	0
Other	48	11	11	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

ALASKA: MAJOR DRAINAGE

<table>
<tr><th rowspan="3">Basin Name</th><th colspan="2" rowspan="2">Existing Hydropower Production Facilities</th><th colspan="6">Large Dam Potential (Greater than 5,000 KW Capacity)</th><th colspan="2" rowspan="2">Small Dam Potential (Less than 5,000 KW)</th><th colspan="2" rowspan="2">Total Basin Potential</th></tr>
<tr><th colspan="2">Rehabilitation Potential (9%)</th><th colspan="2">Hydro Expansion Potential</th><th colspan="2">Hydro Installation Potential</th></tr>
<tr><th>Capacity (MW)</th><th>Output (10^6KWH)</th><th>Capacity (MW)</th><th>Output (10^6KWH)</th><th>Capacity (MW)</th><th>Output (10^6KWH)</th><th>Capacity (MW)</th><th>Output (10^6KWH)</th><th>Capacity (MW)</th><th>Output (10^6KWH)</th><th>Capacity (MW)</th><th>Output (10^6KWH)</th></tr>
<tr><td>Arctic</td><td rowspan="6">123.2</td><td rowspan="6">493.3</td><td rowspan="6">11.1</td><td rowspan="6">44.4</td><td rowspan="6">36.5</td><td rowspan="6">141</td><td rowspan="6">45.9</td><td rowspan="6">238.5</td><td>0</td><td>0</td><td rowspan="6">119</td><td rowspan="6">536</td></tr>
<tr><td>Northwest</td><td>0</td><td>0</td></tr>
<tr><td>Yukon</td><td>0.2</td><td>0</td></tr>
<tr><td>Southwest</td><td>0</td><td>0</td></tr>
<tr><td>South Central</td><td>14.9</td><td>66</td></tr>
<tr><td>Southeast</td><td>10.4</td><td>46</td></tr>
<tr><td></td><td>123.2</td><td>493.3</td><td>11.1</td><td>44.4</td><td>36.5</td><td>141</td><td>45.9</td><td>238.5</td><td>25.5</td><td>112</td><td>119</td><td>536</td></tr>
</table>

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	2	5	3	0
20-49	3	7	3	3
50-99	0	2	2	2
More than 100	0	0	0	3

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	2	0	6	0
Rockfill	2	2	3	0
Gravity	1	0	3	0
Buttress	0	0	0	0
Arch	1	2	0	0
Multi-Arch	0	0	1	0
Other	6	4	2	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

HAWAII: MAJOR DRAINAGE

	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity)						Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
			Rehabilitation Potential (9%)		Hydro Expansion Potential		Hydro Installation Potential					
Basin Name	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
Hawaii-Hawaii Co.	5.0	34.3	0.5	3.1	0	0	0	0	0.2	0.1	0.7	3.2
Maui	5.2	27.5	0.5	2.5	0	0	0	0	0.5	2.1	1.0	4.6
Kahoolawe	0	0	0	0	0	0	0	0	0	0	0	0
Lanai	0	0	0	0	0	0	0	0	0	0	0	0
Molokai	0	0	0	0	0	0	0	0	6.7	5.9	6.7	5.9
Oahu-Oahu Co.	0	0	0	0	0	0	0	0	20.5	20.3	20.5	20.3
Kauai	7.9	42.6	0.7	3.8	1.3	8.0	0	0	2.6	11.6	4.6	23.4
Niihau	0	0	0	0	0	0	0	0	0	0	0	0
	18.1	104.4	1.7	9.4	1.3	8.0	0	0	30.5	40	33.5	57.4

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet)			
	0-99	100-999	1,000-9,999	More than 10,000
0-19	11	4	0	0
20-49	45	47	3	0
50-99	0	5	3	0
More than 100	0	1	0	0

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed			
	Before 1931	1931-1955	1956 to date	Unknown
Earth	97	12	9	0
Rockfill	0	0	0	0
Gravity	0	0	0	0
Buttress	0	0	0	0
Arch	0	0	1	0
Multi-Arch	0	0	0	0
Other	0	0	0	0

REGIONAL HYDROPOWER AND HYDROPOWER POTENTIAL STATISTICS

PUERTO RICO-VIRGIN ISLANDS: MAJOR DRAINAGE

Basin Name	Existing Hydropower Production Facilities		Large Dam Potential (Greater than 5,000 KW Capacity): Rehabilitation Potential (9%)		Hydro Expansion Potential		Hydro Installation Potential		Small Dam Potential (Less than 5,000 KW)		Total Basin Potential	
	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)	Capacity (MW)	Output (10^6KWH)
Puerto Rico (all)	None	listed			No po	tential			10.3	128.8	10.3	128.8
Virgin Islands (all)	"	"			"	"			0	0	0	0

NUMBER OF DAMS SORTED BY HEIGHT AND STORAGE CHARACTERISTICS

Maximum Height (Feet)	Maximum Storage (Acre-Feet): 0-99	100-999	1,000-9,999	More than 10,000
0-19	2	0	0	0
20-49	6	2	0	0
50-99	0	3	5	2
More than 100	0	1	4	8

NUMBER OF DAMS SORTED BY TYPE AND AGE

Type of Dam	Year Dam Completed: Before 1931	1931-1955	1956 to date	Unknown
Earth	3	8	2	0
Rockfill	0	1	0	0
Gravity	2	10	3	0
Buttress	3	0	0	0
Arch	0	0	0	0
Multi-Arch	0	0	0	0
Other	0	0	1	0

APPENDIX C

EXISTING REGIONAL RESERVOIR STORAGE

The following tables summarize the predominate use of existing reservoir storage in each of the major drainage basins of the United States. The reservoir volumes correspond to the maximum available storages behind existing dams in each region and do not account for shared or allocated storage for multiple-purpose reservoirs; i.e., if a reservoir was primarily built for flood control, all available storage has been assigned to the flood control category even though the reservoir is now being used for other purposes as well.

All of the listed purposes of reservoir storage are in a sense competitors with hydropower. If no reallocation of storage were contemplated, then the only water available for hydropower generation would be the currently required minimum releases for downstream flows, water normally spilled prior to or during floods, water automatically released through low-flow conduits, and any other inflows not currently stored or withdrawn for authorized purposes.

Table C-1

REGION: NEW ENGLAND

RIVER BASINS INCLUDED:
- St. John-St. Croix
- Penobscot
- Kennebec-Androscoggin
- Saco
- Merrimack
- Massachusetts-Rhode Island Coastal
- Long Island Sound
- Connecticut
- St. Francis

Total Number of Dams: 2866

Total Maximum Storage: 21.612 (10^6a-f)

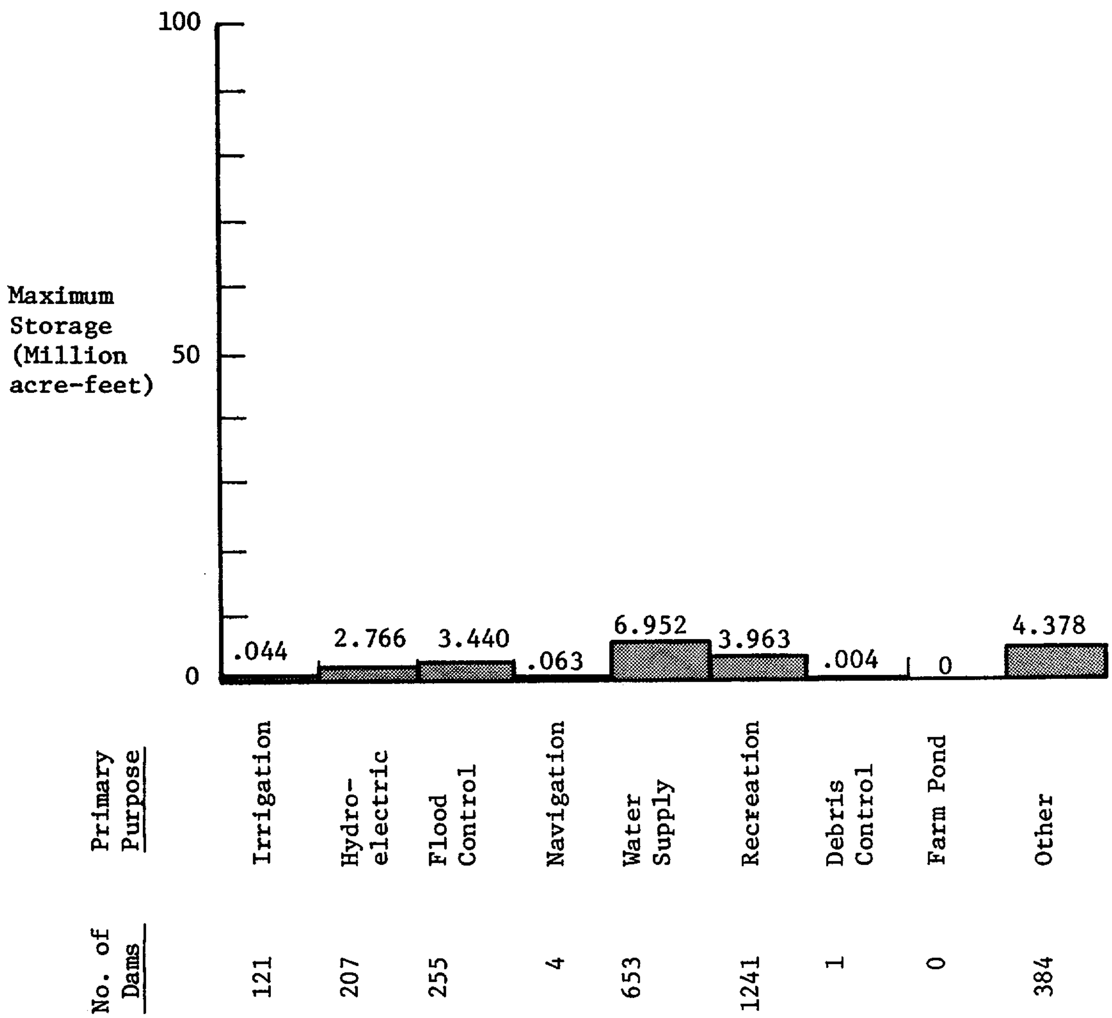

Table C-2

REGION: MIDDLE ATLANTIC

RIVER BASINS INCLUDED:
- Richelieu
- Upper Hudson
- Lower Hudson
- Delaware
- Susquehanna
- Upper Chesapeake Bay
- Potomac
- Lower Chesapeake Bay

Total Number of Dams: 2969

Total Maximum Storage: 119.230 (10^6a-f)

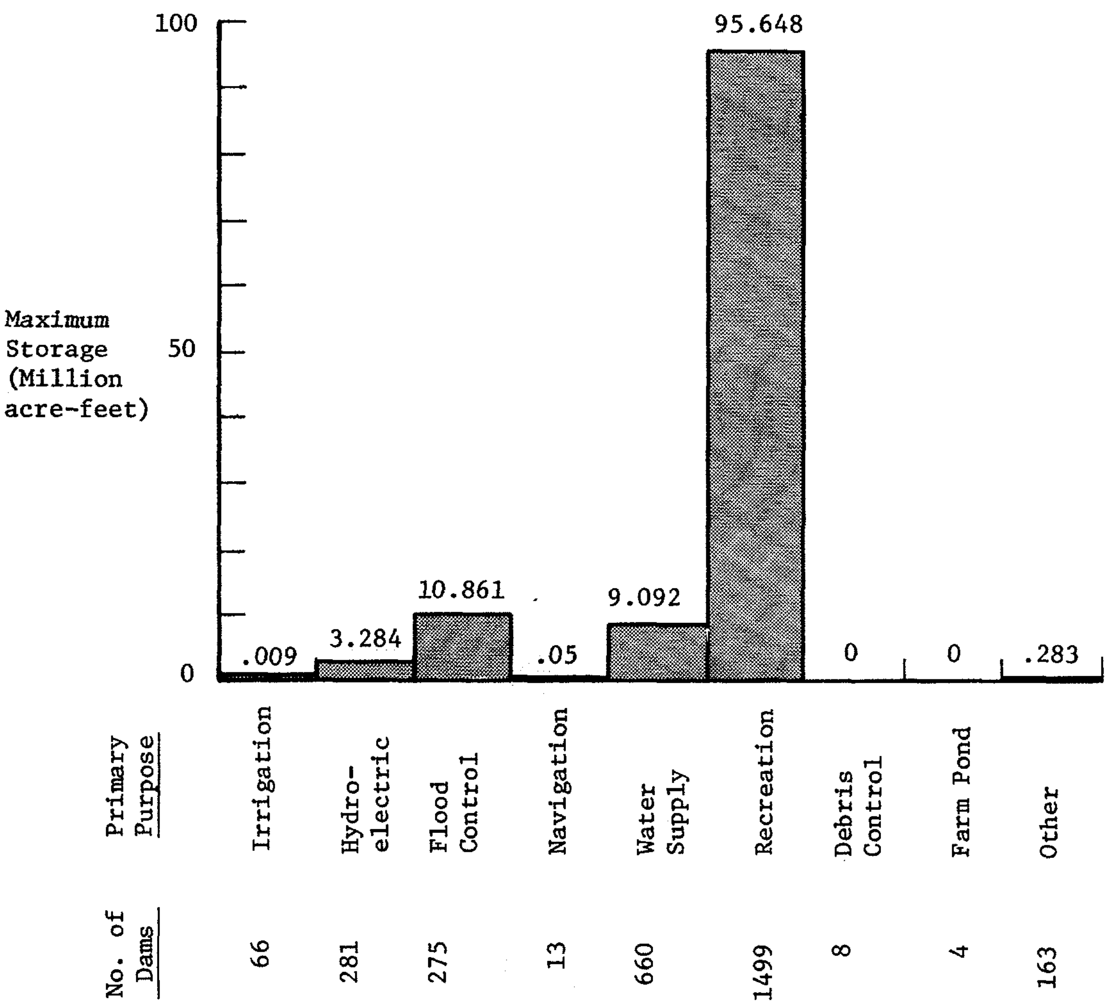

Table C-3

REGION: SOUTH ATLANTIC GULF

RIVER BASINS INCLUDED:

Roanoke	Tampa Bay
Tar-Neuse	Suwannee
Cape Fear	Ochlockonee
Pee Dee	Apalachicola
Santee-Edisto	St. Josephs-Perdido
Savannah-Ogeechee	Alabama
Altamaha-St. Marys	Tombigbee
St. Johns	Pascagoula
Southern Florida	Pearl

Total Number of Dams: 6924

Total Maximum Storage: 219.277 (10^6a-f)

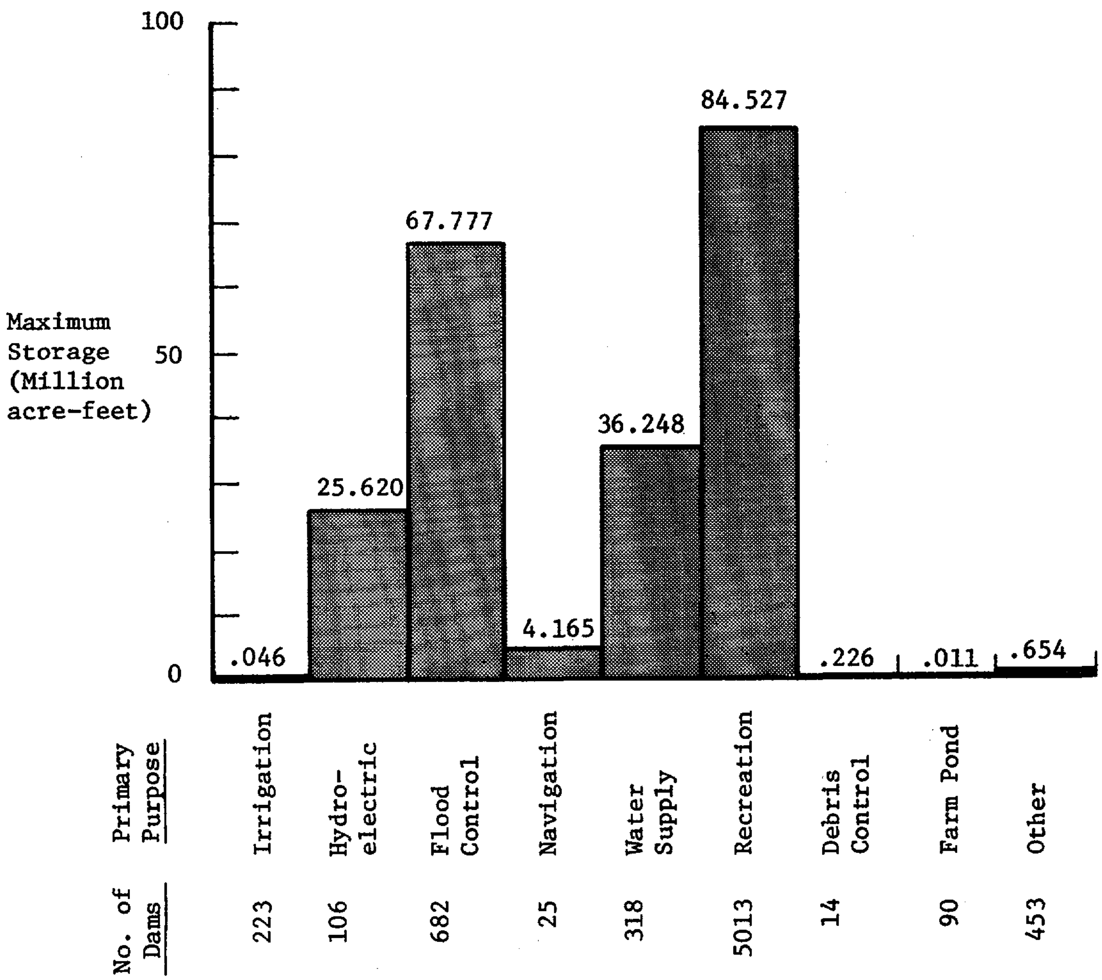

Table C-4

REGION: GREAT LAKES

RIVER BASINS INCLUDED:

Western Lake Superior
Southern Lake Superior
Southwestern Lake Michigan
Southeastern Lake Michigan
Northeastern Lake Michigan
Northwestern Lake Michigan
Northwestern Lake Huron
Southwestern Lake Huron
St. Clair-Detroit
Western Lake Erie
Southern Lake Erie
Eastern Lake Erie
Southwestern Lake Ontario
Southeastern Lake Ontario
Northeastern Lake Ontario-St. Lawrence

Total Number of Dams: 1244

Total Maximum Storage: 210.139 (10^6 a-f)

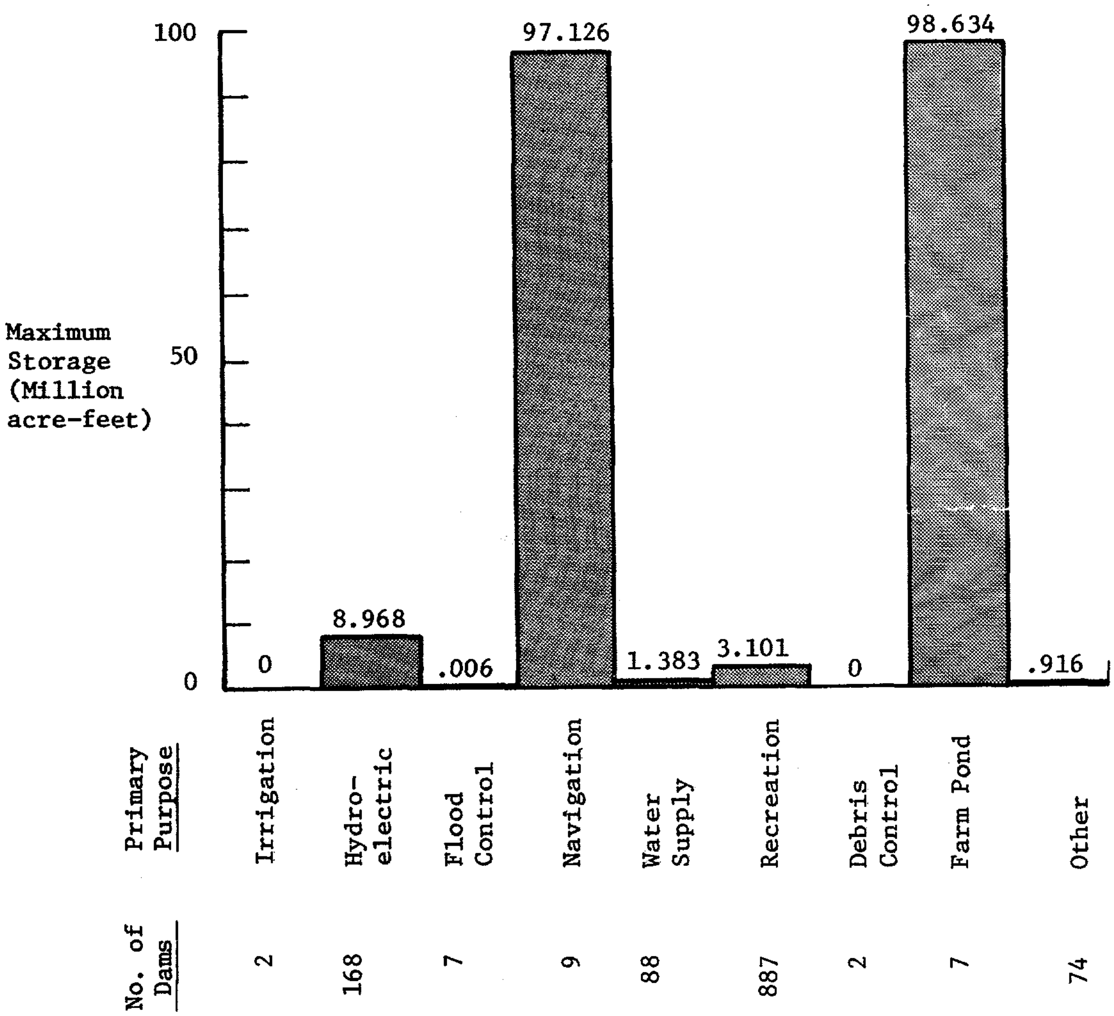

Table C-5

REGION: OHIO

RIVER BASINS INCLUDED:
- Allegheny
- Monongahela
- Pittsburgh-Wheeling-Beaver
- Muskingum
- Kanawha
- Scioto
- Portsmouth-Little Kanawha-Big Sandy
- Great Miami
- Cincinnati-Little Miami
- Licking and Kentucky
- Louisville-Salt
- White and Patoka
- Wabash
- Cumberland
- Evansville-Green

Total Number of Dams: 2862

Total Maximum Storage: 483.519 (10^6a-f)

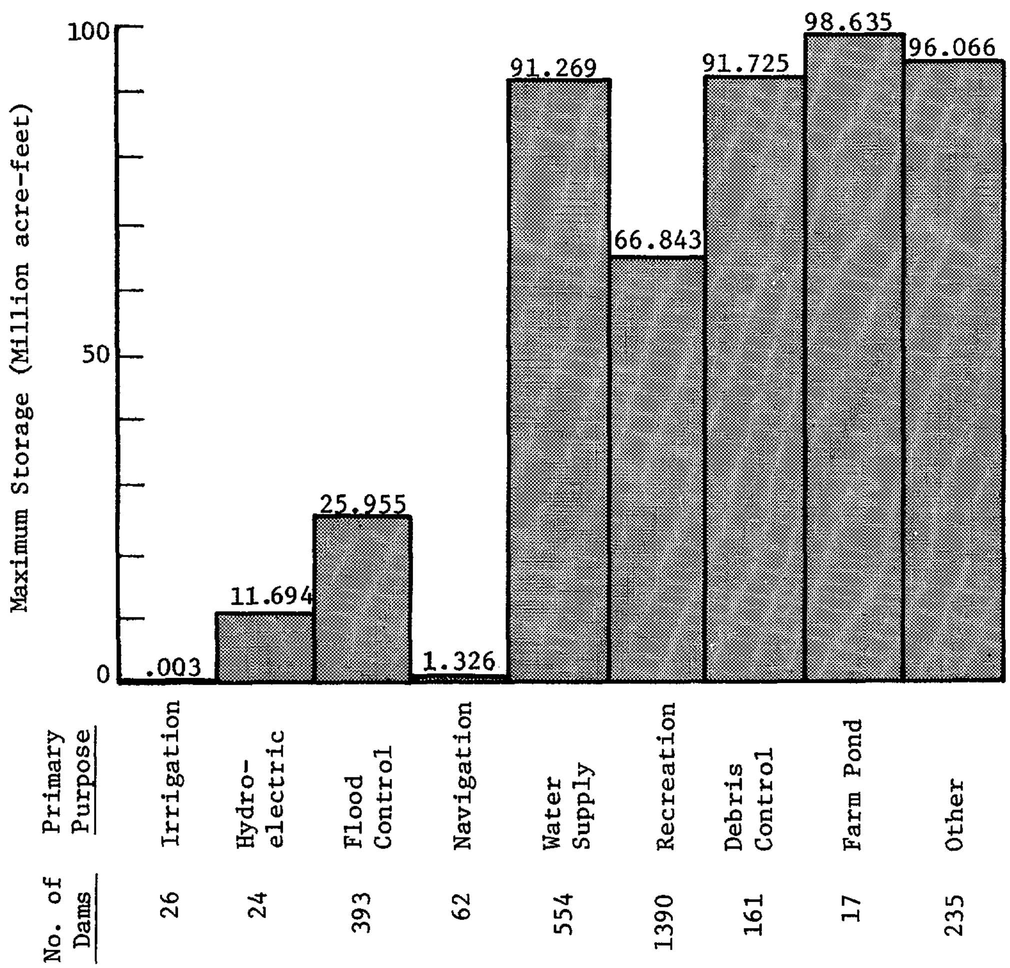

Table C-6

REGION: TENNESSEE

RIVER BASINS INCLUDED:
Upper Tennessee
Tennessee-Hiwassee-Sequatchie
Tennessee-Elk
Lower Tennessee

Total Number of Dams: 459

Total Maximum Storage: 23.712 (10^6a-f)

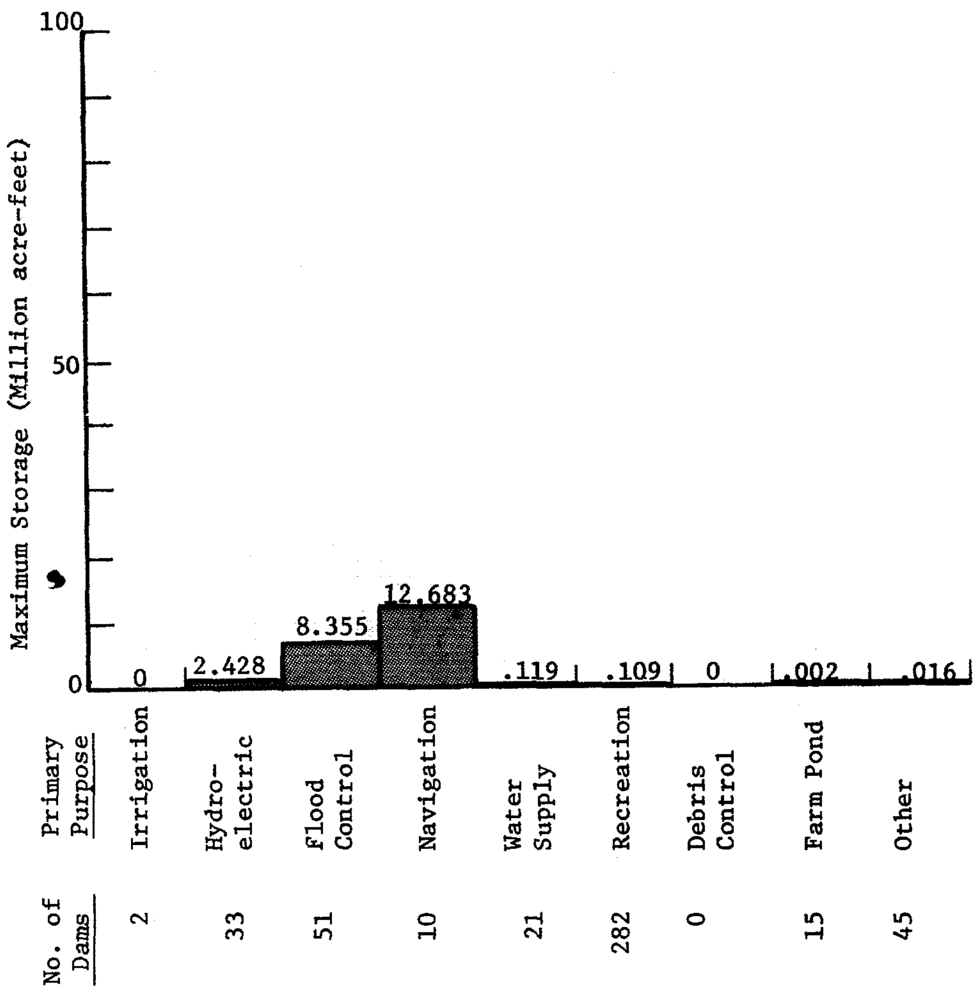

Table C-7

REGION: UPPER MISSISSIPPI

RIVER BASINS INCLUDED:
Minnesota
Mississippi Headwaters
St. Croix
Chippewa
Mississippi-Black-Root
Wisconsin
Mississippi-Maquoketa-Plum
Rock
Des Moines
Mississippi-Iowa-Quad Cities
Mississippi-Salt-Quincy
Upper Illinois
Lower Illinois
Mississippi-Kaskaskia-St. Louis

Total Number of Dams: 3329

Total Maximum Storage: 110.672 (10^6a-f)

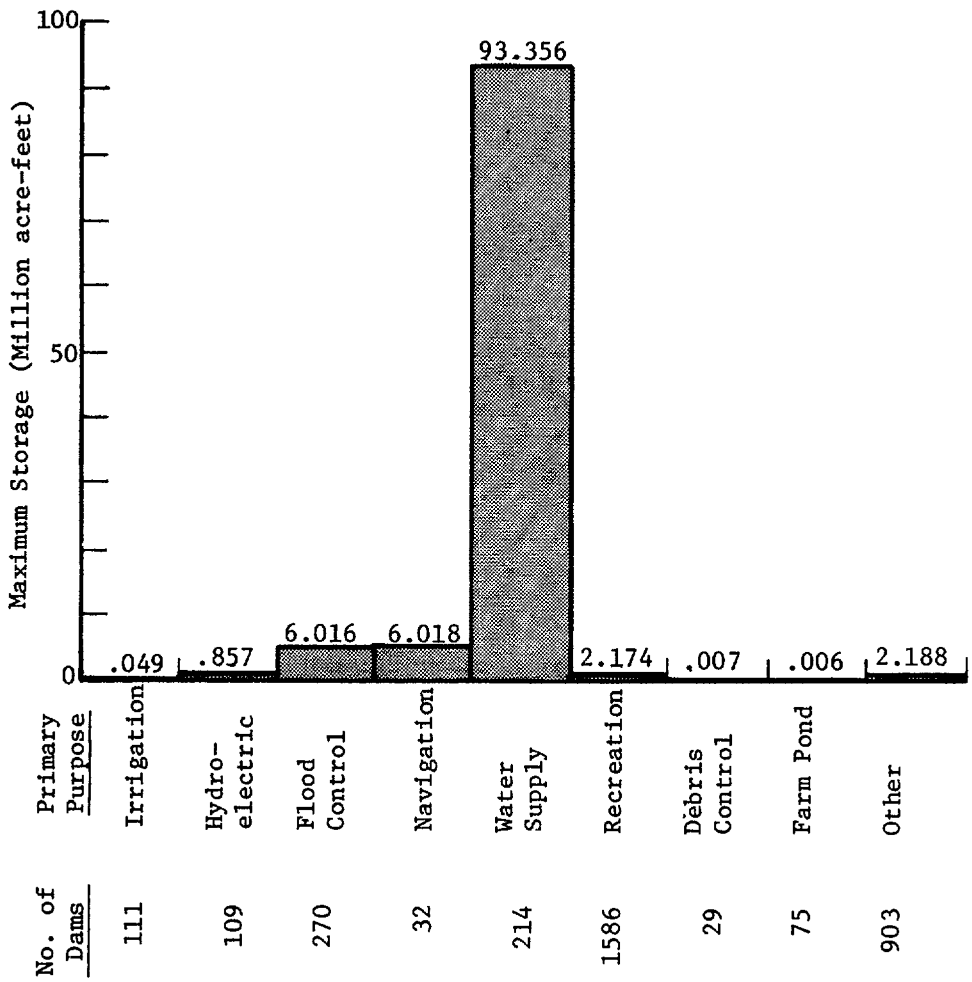

Table C-8

REGION: LOWER MISSISSIPPI

RIVER BASINS INCLUDED:
- Mississippi-Hatchie
- Mississippi-St. Francis
- Mississippi-Yazoo
- Ouachita
- Mississippi-Tensas
- Mississippi-Big Black
- Mississippi-Lake Maurepas
- Louisiana Coastal
- Mississippi Delta

Total Number of Dams: 2559

Total Maximum Storage: 20.191 (10^6a-f)

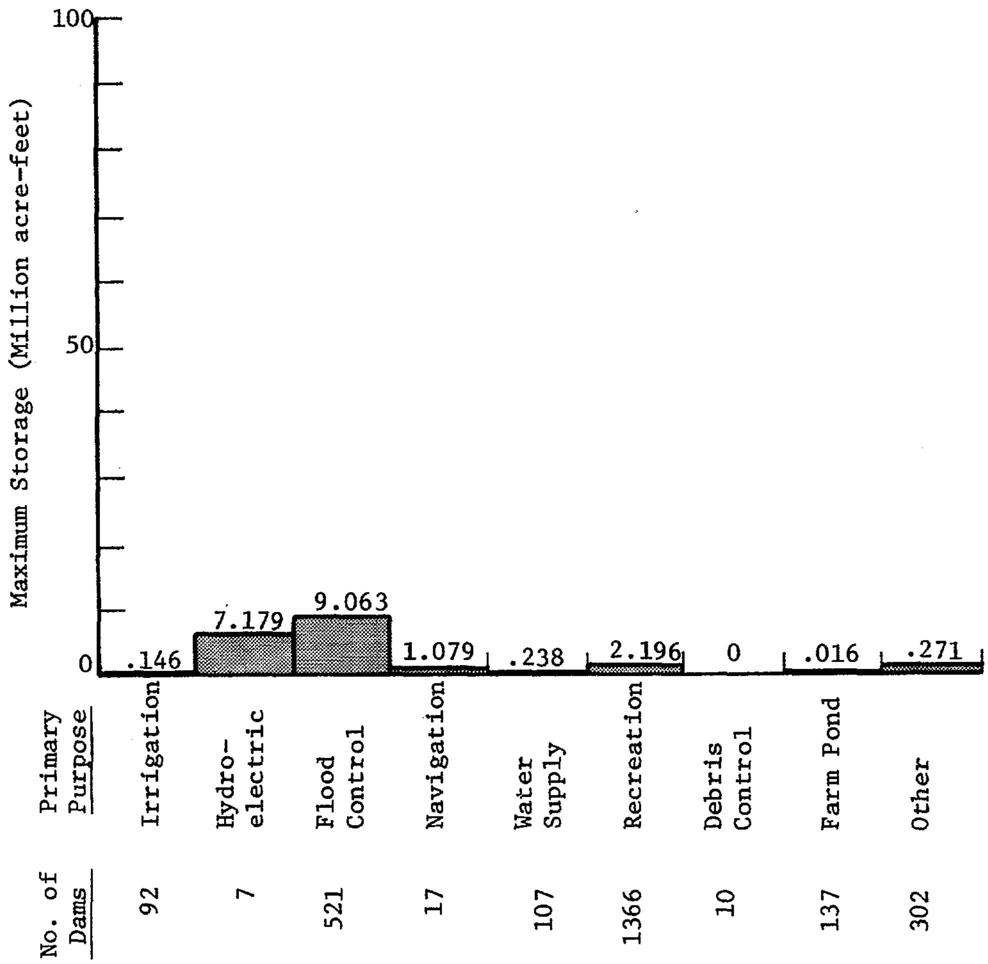

Table C-9

REGION: SOURIS-RED-RAINY

RIVER BASINS INCLUDED:
Souris
Red
Rainy

Total Number of Dams: 304

Total Maximum Storage: 7.558 (10^6a-f)

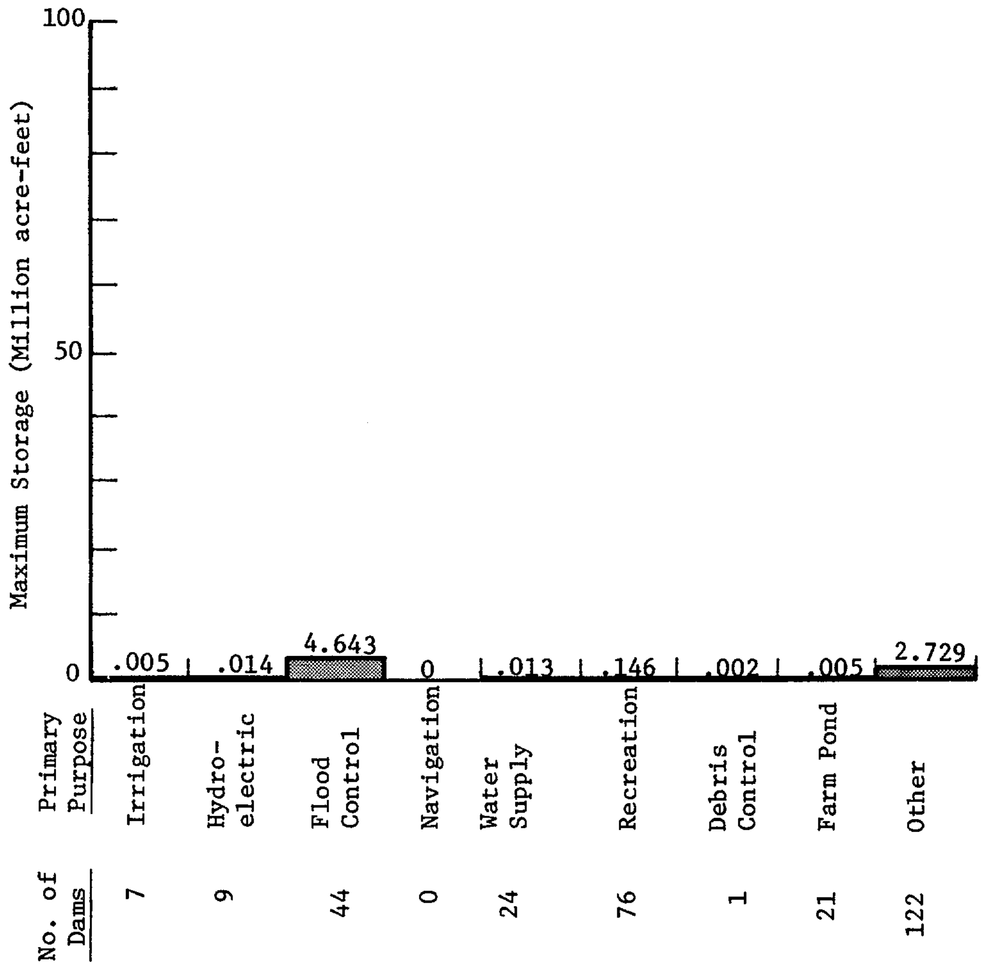

Table C-10

REGION: MISSOURI

RIVER BASINS INCLUDED:

St. Mary	James
Missouri Headwaters	Missouri-Big Sioux
Missouri-Marias	North Platte
Missouri-Musselshell	South Platte
Milk	Loup River
Missouri-Poplar	Platte
Upper Yellowstone	Elkhorn
Bighorn	Missouri-Sioux City-Omaha
Tongue-Powder	Missouri-Nemaha-Nodaway
Lower Yellowstone	Republican
Missouri-Little Missouri	Smoky Hill
Cheyenne	Kansas
Missouri-Oahe	Grand-Chariton
Missouri-White	Osage-Gasconade
Niobrara	
Missouri-Kansas City	

Total Number of Dams: 11,971   Total Maximum Storage: 115.456 (10^6a-f)

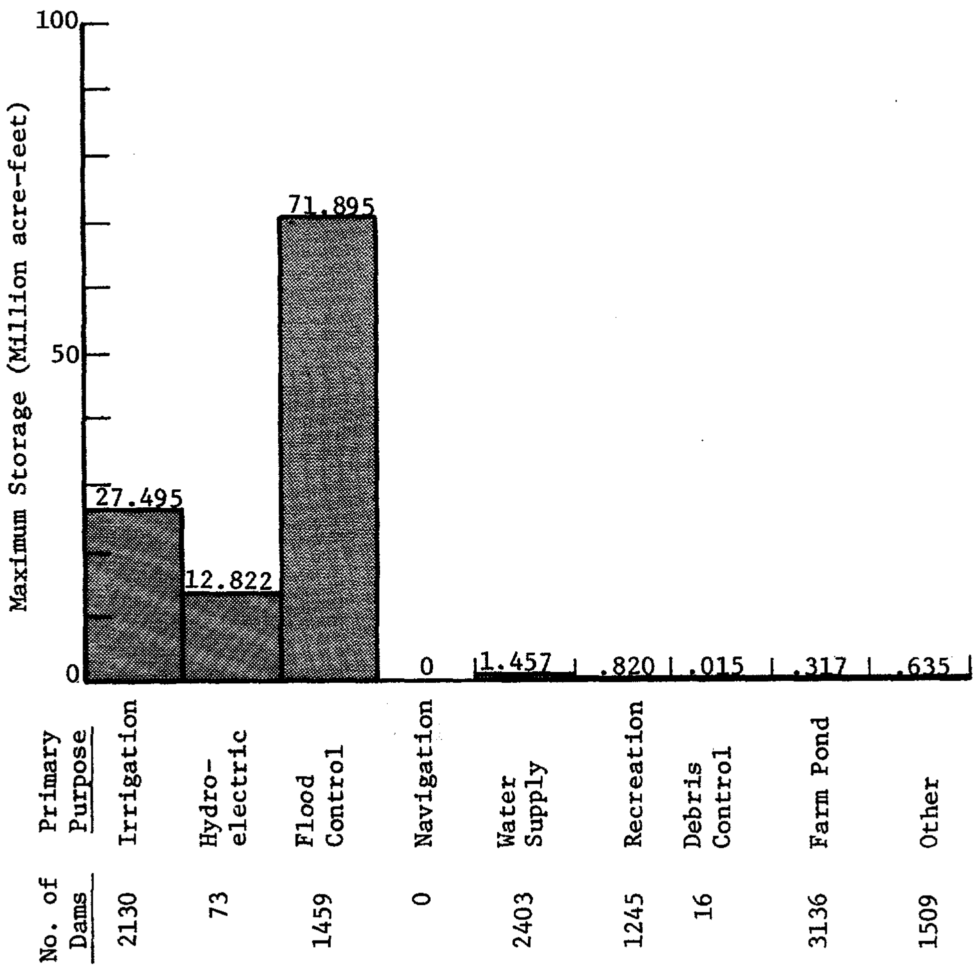

Table C-11

REGION: ARKANSAS-WHITE-RED

RIVER BASINS INCLUDED:
- White
- Upper Arkansas
- Arkansas in Kansas
- Upper Cimarron
- Lower Cimarron
- Arkansas-Keystone
- Verdigris-Neosho
- Upper Canadian
- Canadian in Texas
- Lower Canadian
- Red River Headwaters
- Red-Washita
- Lower Red
- Lower Arkansas

Total Number of Dams: 5097

Total Maximum Storage: 69.867 (10^6a-f)

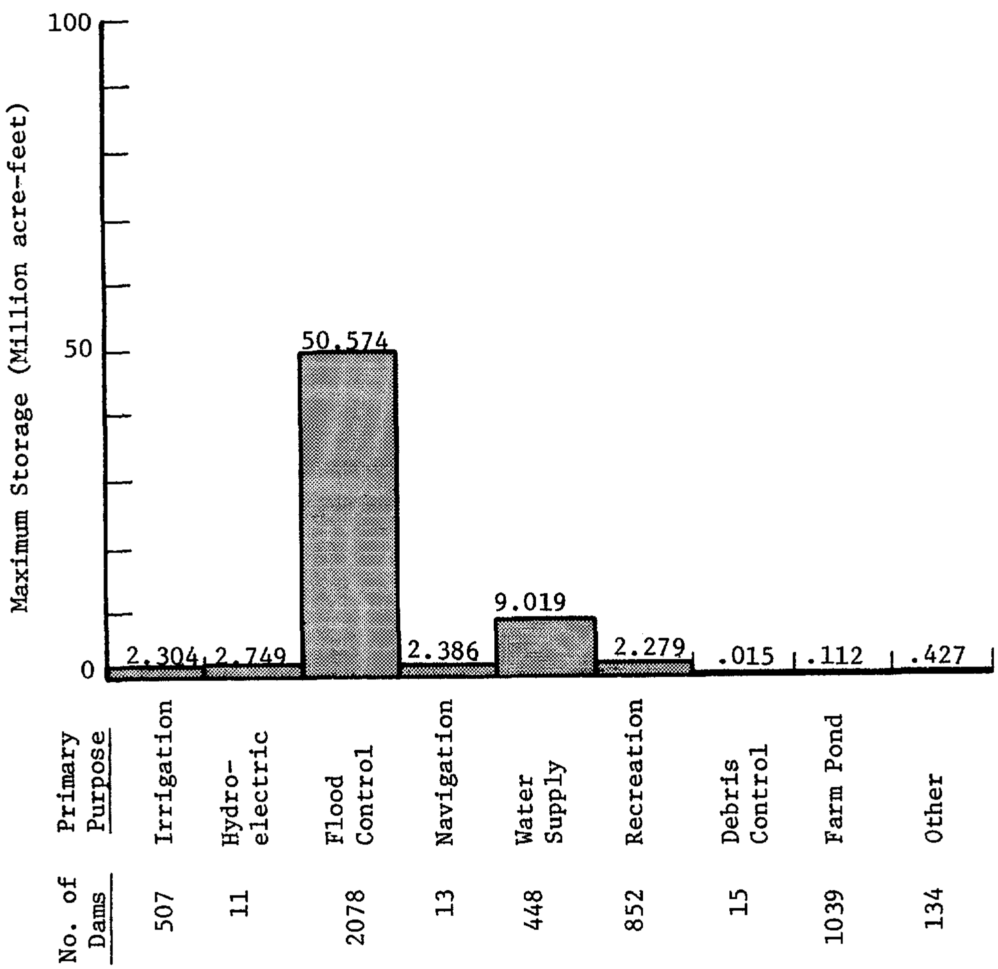

Table C-12

REGION: TEXAS-GULF

RIVER BASINS INCLUDED:
- Sabine
- Neches
- Upper Trinity
- Lower Trinity
- Brazos Headwaters
- Middle Brazos
- Lower Brazos
- Colorado (Texas) Headwaters
- Lower Colorado-Llano
- Guadalupe-San Antonio
- Nueces-Frio

Total Number of Dams: 3535

Total Maximum Storage: 55.422 (10^6a-f)

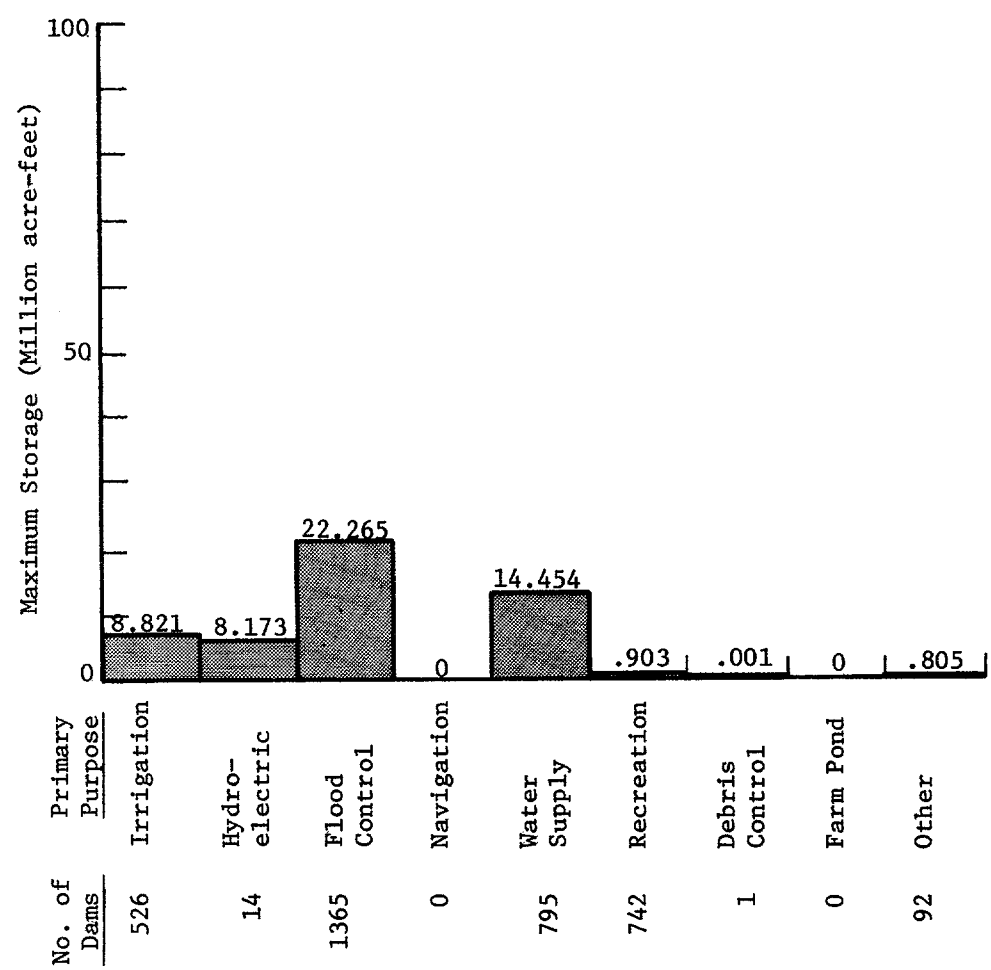

Table C-13

REGION: RIO GRANDE

RIVER BASINS INCLUDED:
- Rio Grande Headwaters
- North Rio Grande
- Rio Grande-Mimbres
- Rio Grande-Big Bend
- Rio Grande Closed Basins
- Upper Pecos
- Lower Pecos
- Rio Grande-Amistad
- Lower Rio Grande

Total Number of Dams: 448

Total Maximum Storage: 14.411 (10^6a-f)

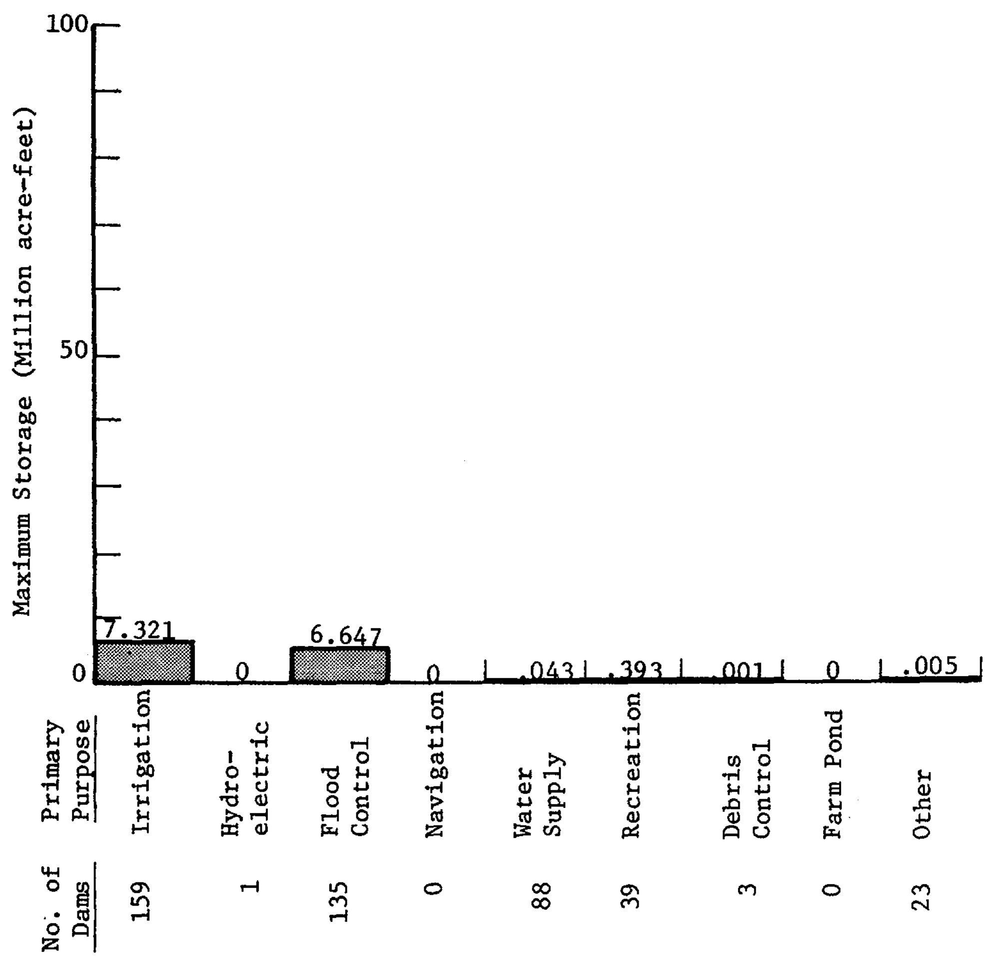

Table C-14

REGION: UPPER COLORADO

RIVER BASINS INCLUDED:
- Upper Green
- Yampa-White
- Lower Green
- Gunnison
- Colorado Headwaters
- Colorado-Dolores
- Upper San Juan
- Colorado-San Juan

Total Number of Dams: 1018

Total Maximum Storage: 12.366 (10^6a-f)

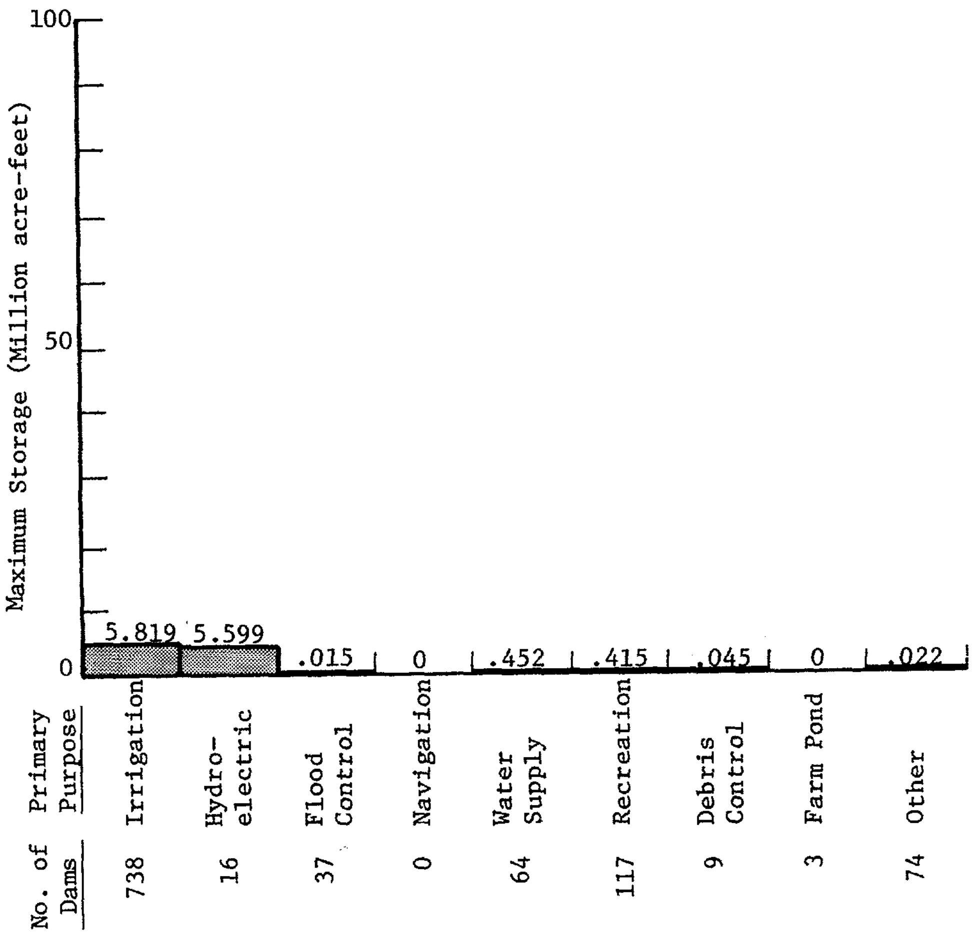

Table C-15

REGION: LOWER COLORADO

RIVER BASINS INCLUDED:
Little Colorado
Colorado-Lake Mead
Upper Gila
Gila-San Pedro
Gila-Salt
Colorado-Lake Mojave

Total Number of Dams: 419

Total Maximum Storage: 72.111 (10^6a-f)

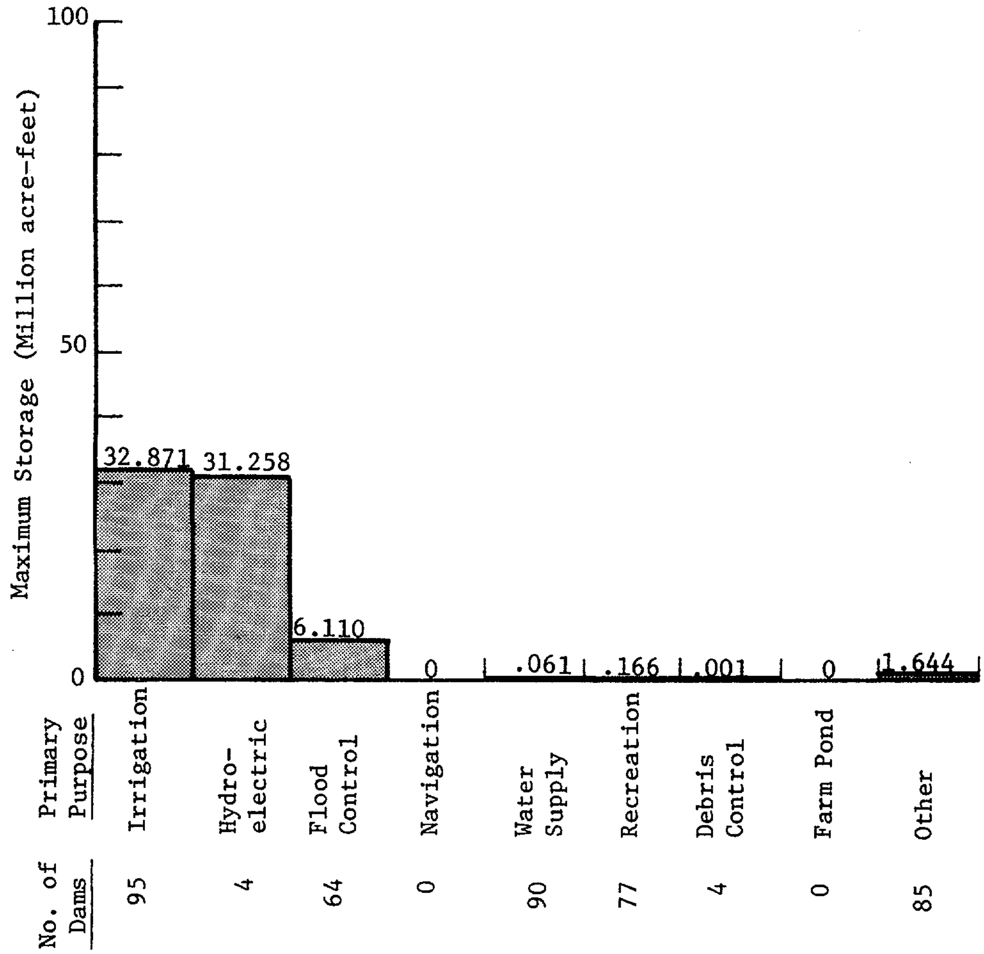

Table C-16

REGION: GREAT BASIN

RIVER BASINS INCLUDED:
Bear
Great Salt Lake
Sevier Lake
Humboldt
Central Lahontan
Tonopah Desert

Total Number of Dams: 436

Total Maximum Storage: 4.200 (10^6a-f)

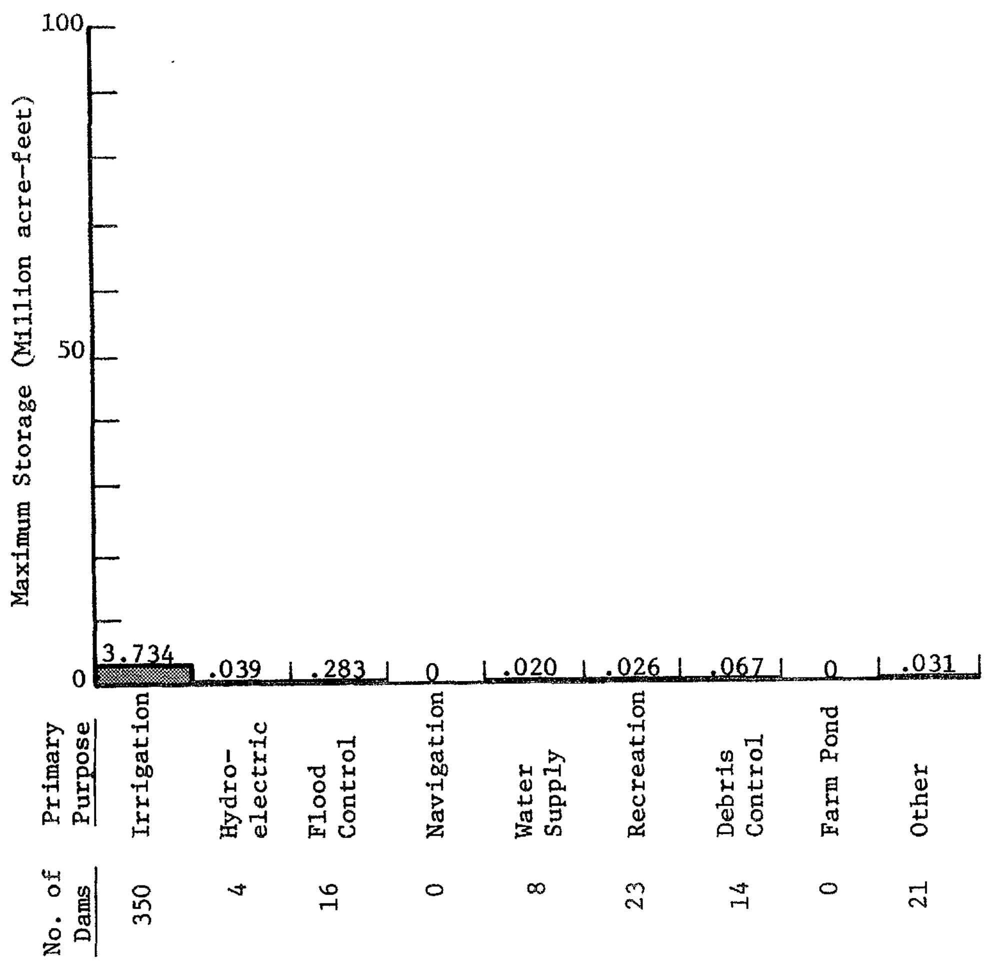

Table C-17

REGION: COLUMBIA-NORTH PACIFIC

RIVER BASINS INCLUDED:

Kootenai	Deschutes
Pend Oreille	Middle Columbia
Spokane	Willamette
Yakima	Lower Columbia
Upper Snake	Puget Sound
Middle Snake	Washington Coastal
Salmon	Oregon Coastal
Lower Snake	Oregon Closed Basin
Upper Columbia	

Total Number of Dams: 1364

Total Maximum Storage: 68.007 (10^6a-f)

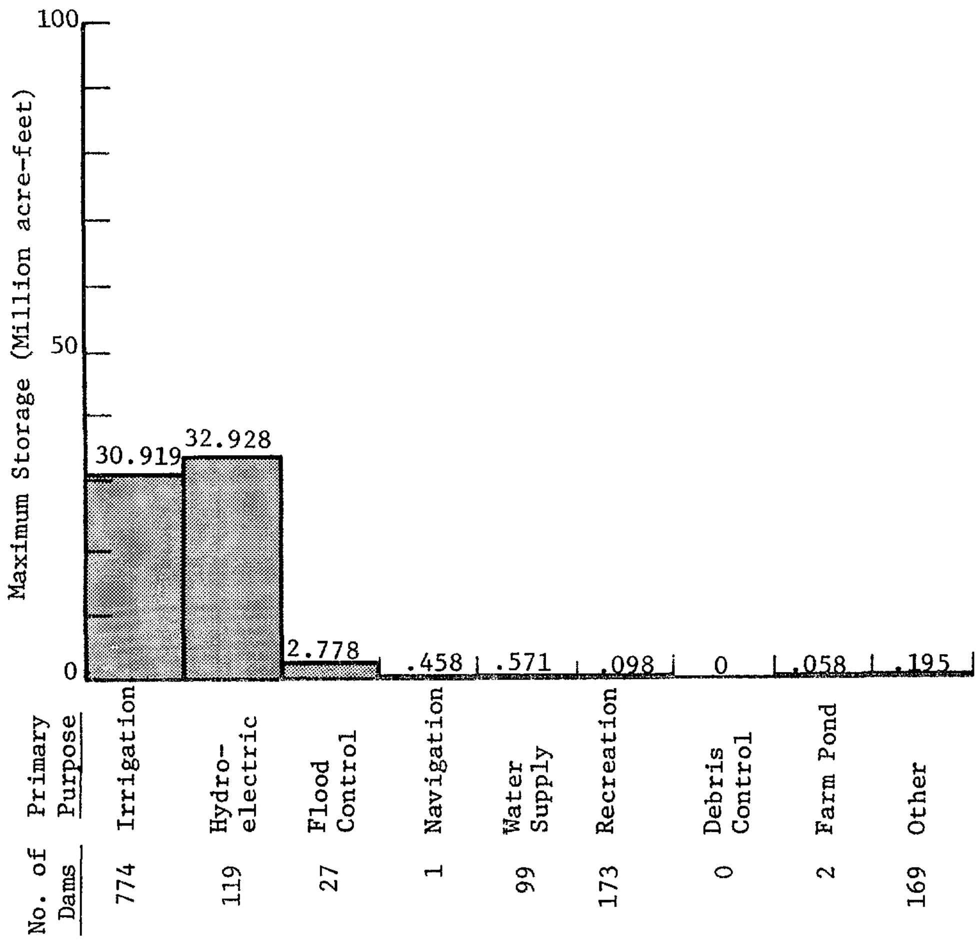

Table C-18

REGION: CALIFORNIA-SOUTH PACIFIC

RIVER BASINS INCLUDED:
North Coastal
Sacramento Basin
Tulare Basin
San Joaquin
Delta Central Sierra
San Francisco Bay
Central Coastal
South Coastal
South Lahontan
Colorado Desert

Total Number of Dams:1249

Total Maximum Storage: 146.163 (10^6a-f)

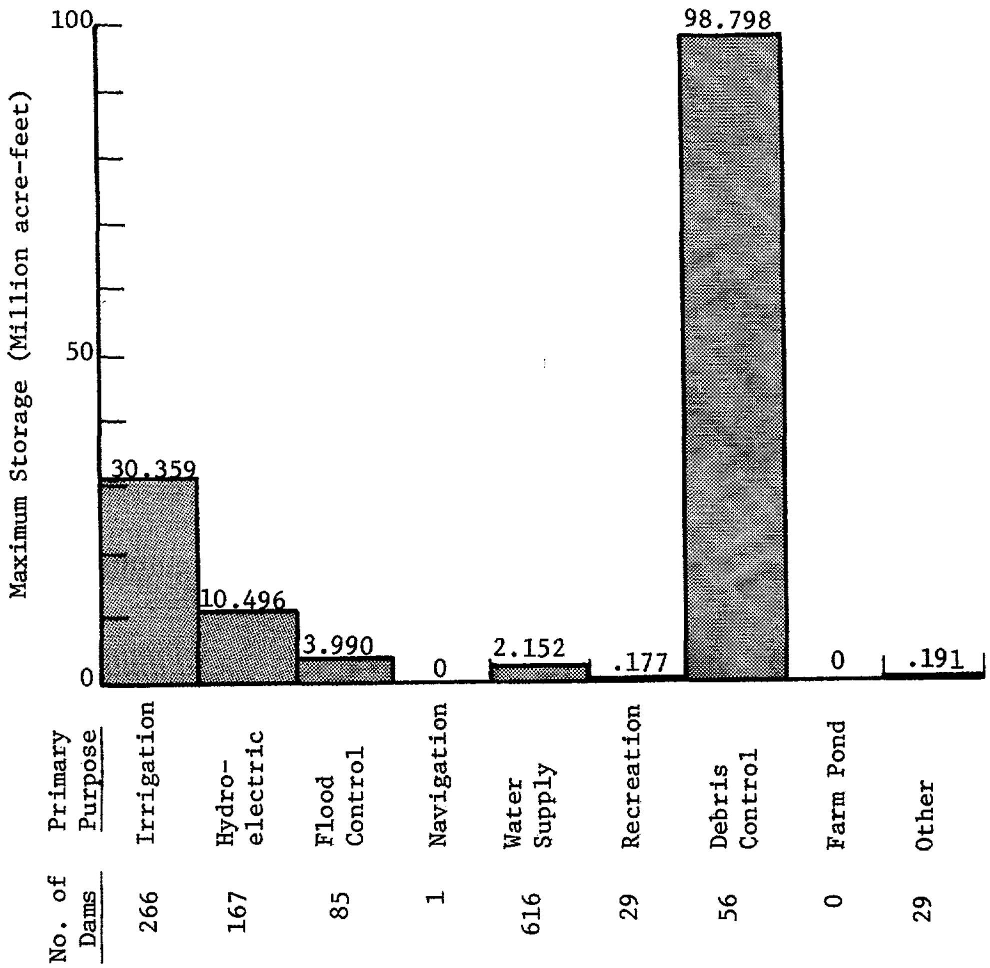

Table C-19

REGION: ALASKA

RIVER BASINS INCLUDED:
Arctic
Northwest
Yukon
Southwest
South Central
Southeast

Total Number of Dams: 35

Total Maximum Storage: .870 (10^6a-f)

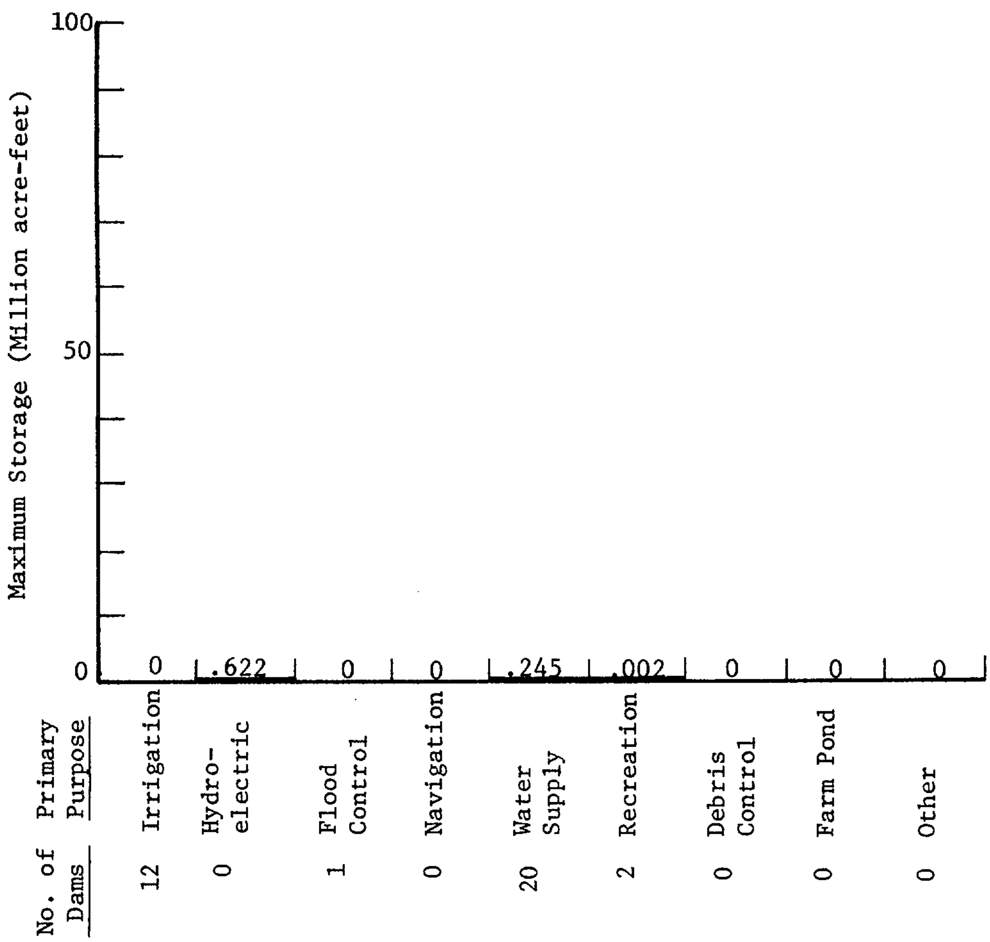

Table C-20

REGION: HAWAII

RIVER BASINS INCLUDED:
Hawaii-Hawaii Co.
Maui
Kahoolawe
Lanai
Molokai
Oahu - Oahu Co.
Kauai
Niihau

Total Number of Dams: 119

Total Maximum Storage: .053 (10^6a-f)

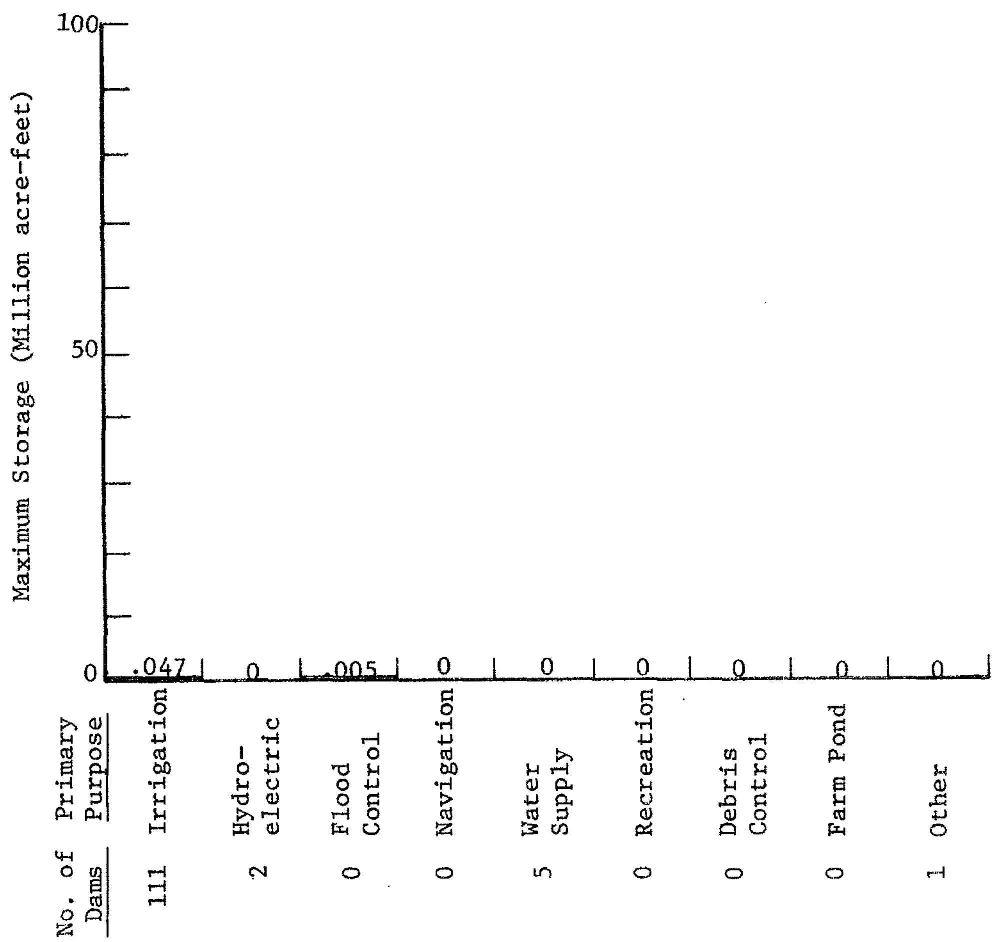

Table C-21

REGION: PUERTO RICO & VIRGIN ISLANDS

RIVER BASINS INCLUDED:
Puerto Rico
Virgin Islands

Total Number of Dams: 33

Total Maximum Storage: .406 (10^6a-f)